

Automatic Detection of B-Lines in Vivo Lung Ultrasound by Using Bottom Hat Transform

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Abstract: Lung ultrasound imaging is widely used for the diagnosis of pulmonary diseases because it is safe, portable, and does not expose patients to radiation. In lung ultrasound images, B lines appear as vertical artifacts that originate from the pleural line and extend to the bottom of the image. The presence and number of B lines provide important clinical information about lung conditions such as pulmonary edema and interstitial syndrome. Manual identification of these artifacts requires expert knowledge and may lead to inconsistent interpretations. This paper presents an automated approach for detecting B lines in lung ultrasound images using image processing techniques. The proposed method includes image preprocessing, pleural line detection, morphological filtering, and bottom hat transformation to enhance vertical artifacts. The detected B lines are then analyzed to assist in identifying abnormal lung conditions. The proposed system improves detection reliability and can support medical professionals in faster and more accurate diagnosis.

Keywords: Lung Ultrasound, B Line Detection, Image Processing, Medical Image Analysis, Pulmonary Disease Detection.

1.Introduction

Recent years have seen a rise in the use of lung ultrasound (LUS), a non-invasive imaging technique that allows for a rapid visual assessment of the lung tissue and pleura. LUS relies on B-lines, which are significant artifacts of ultrasonography, to diagnose lung illness [1-3]. The pleura gives rise to these vertical hyper echoic reverberation artifacts, which are described as discrete and move in sync with the movement of the lungs. They also spread down the screen without fading [4-7]. Lung health is defined by a close relationship between air and water. One symptom of lung illness is a change in their equilibrium. Ultrasound lung scans produce a number of abnormalities due to the interactions between air and water; thus, a LUS picture of pulmonary disease is dependent on assessing these artifacts while visualizing the structures. Reverberation artifacts, or B-lines, are caused by the many reflections of the ultrasonic beam that become stuck between structures that are rich in air and structures that are rich in water [8-12]. Beginning with the serous membrane that covers the surface of the lungs, known as the visceral pleura, they extend all the way to the edge of the screen. Lung edema, which is common in patients with heart and lung disorders and those who have had significant surgery, can be evaluated with LUS imaging with B-line detection. B-lines have also been utilized to rank the severity of interstitial lung disorders in patients [13-15].

Commonly used in clinical practice, X-ray imaging of patients suspected of having pulmonary edema is routinely repeated at short intervals to track the treatment's efficacy [16]. Despite lung ultrasound's long history of use, it is frequently disregarded by healthcare providers who are unfamiliar with the technique. Edema was linked to Blines in ultrasonography and chest



CT scans in a 1997 study by Lichtenstein [17-20]. The diagnostic utility of B-line artifacts was demonstrated for the first time, despite the fact that LUS had previously been utilized for pleural effusion evaluation. Picano demonstrated in 2004 that X-ray results for evaluating the presence of extra-vascular lung water (EVLW) correlate with the amount of B-lines observed by LUS [21-22]. B-lines have been clinically and methodologically used for the diagnosis of lung illnesses in a number of investigations since then. Conventional ultrasonography methods for the diagnosis of pulmonary edema rely on visual examination and interpretation of B-lines [23-24].

A diagnosis of diffuse alveolar-interstitial syndrome (resulting from hydrostatic pulmonary edema, lesional pulmonary edema, or fibrosis) is made when many B-lines are spread out bilaterally in additional images of each lung. Examining the quantity of B-lines in a particular scan or frame is the usual procedure for pathologists to diagnose this condition. According to research conducted by intensivists, the maximum width between B-lines that should be considered important is 7 mm, which is the average distance between two B-lines on the surface of the lung. In order to identify edema, another study utilized the criterion of counting three artifacts with a spacing between consecutive lines of no more than 7mm. Contrarily, it was regarded a typical result to see a single B-line or numerous B-lines that were more than 7 mm apart in a single scan. Interpretation error owing to habituation and lack of expertise are major factors impacting the accuracy of the assessment. There is hope that computer-assisted interpretation can help users overcome these mistakes and embrace the technology. The presence of B-lines was investigated in a large multicenter research (n=1005) using a six-zone scanning procedure. Clinical assessment and chest radiography were not as accurate as the LUS method in distinguishing acute decompensated heart failure from noncardiac causes of acute dyspnea. For point-of-care ultrasonography, researchers ran yet another big prospective study (n=788). Compared to the control group, patients treated with point-of-care ultrasonography (PCU) had better diagnoses and quicker treatments using LUS. Ultrasound with B-lines for the diagnosis of acute cardiogenic pulmonary edema (ACPE) in patients presenting to the ED with acute dyspnea was the major focus of a 2014 systematic review investigation. Findings demonstrated a sensitivity of 94.1% and a specificity of 92.4% for US using B-lines to diagnose ACPE. In this context, the results demonstrated the potential of point-of-care lung ultrasonography as a diagnostic tool.

2. Literature Survey

In 1997, Lichtenstein et al. first identified B-lines as important ultrasound artifacts. They observed that vertical bright lines in lung ultrasound images correlate with pulmonary edema. Their study proved that lung ultrasound can indirectly indicate excess fluid in lungs.

In 2004, Picano et al. correlated the number of B-lines with chest X-ray findings. They showed that increasing B-lines indicate extra-vascular lung water. In 2009, Soldati et al. defined standard rules: B-line spacing, Normal vs pathological patterns. These studies strengthened the medical acceptance of lung ultrasound. In 2013, Brattain et al. proposed automatic B-line detection using angular features and thresholding. In 2016, Moshavegh et al. introduced: Pleural line detection using random walk Morphological filtering for B-line extraction Semi-automatic approaches.

To accurately detect and visualize B-lines in ultrasound lung scans, which give a quantitative estimate for the number of B-lines present, the authors of the 2019 research by Ramin Moshavegh et al. suggest an automated method. The BK3000 ultrasound scanner from BK Ultrasound in Denmark was utilized to obtain all the scans for this study. The transducer used was a 5.5 MHz model from BK Ultrasound. For the B-line test, four healthy people and four

patients with pulmonary edema following major surgery were scanned at four different places on each lung. For every subject, we obtained eight sets of fifty frames, for a grand total of sixty-four sets. The 3200 in-vivo lung ultrasound pictures were processed using the algorithm that was suggested. The average number of B-lines in patient scans was 0.28 ± 0.06 (Mean $\pm$ Std), while in healthy people it was 0.03 ± 0.06 (Mean $\pm$ Std). The suggested algorithm successfully distinguished between the healthy volunteers and the patients, as shown by the Mann-Whitney test, which revealed a statistically significant difference between the two groups (p-value = 0.015). Finally, the system can be used to objectively and automatically quantify the distribution of B-lines in pulmonary edema diagnosis.

Motivation for the Proposed Approach

The findings of current methods for identifying and evaluating patterns in medical images are not always accurate and dependable due to issues including inadequate preprocessing and weak feature enhancement. There is a higher chance of human mistake and introduction of subjectivity in many conventional approaches because they depend on manual or semi-automatic analysis. Also, these algorithms might not be able to pick up on finer details in the photographs. We suggest using Morphological Bottom-Hat Transformation as a powerful preprocessing strategy to overcome these issues. This technique makes it easier to isolate small vertical structures, such B-lines, by reducing the visibility of the backdrop and amplifying their contrast with the patterns of adjacent tissues. Automated detection algorithms can work more reliably and precisely if these features are made more visible. Hence, to increase diagnostic performance, the suggested method seeks to raise picture quality, lower subjectivity, and allow trustworthy automatic detection.

3. Proposed System

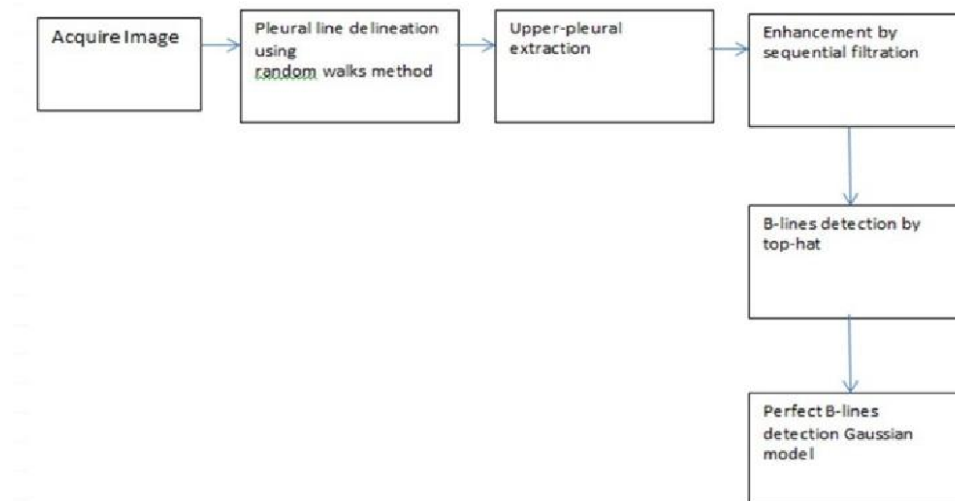


Figure 1: Proposed System

The proposed system for automatic detection of B lines in lung ultrasound images follows a structured image processing workflow. All stages of the system including image acquisition, preprocessing, morphological filtering, Bottom Hat transformation, and B line detection are implemented in a consistent manner to ensure reliable results. The parameters used for image processing operations are carefully selected and maintained throughout the analysis. This consistency helps in achieving accurate detection of vertical artifacts present in lung ultrasound

images. The block diagram and flowchart presented in this paper represent the overall workflow of the system and should be interpreted as part of the complete detection framework. Therefore, the structure of the proposed methodology should be maintained without unnecessary modifications to ensure the clarity and effectiveness of the detection process.

A. Selecting of Dataset and input images

First, ensure that the lung ultrasound images used for the project are appropriate for analysis. In this work, lung ultrasound images are selected as the primary input for detecting B lines. The images should be clear and suitable for processing so that vertical artifacts can be accurately identified. These images are then prepared for further analysis using image processing techniques. Proper selection of ultrasound data is important because it directly affects the accuracy and reliability of the B line detection system.

B. Image Preprocessing

In this stage, the input lung ultrasound images are prepared for further analysis. Ultrasound images often contain noise and low contrast, which can affect the detection process. Therefore, preprocessing techniques such as noise reduction and contrast enhancement are applied. These methods help improve the visibility of important structures in the image, especially the pleural line and vertical artifacts. Proper preprocessing ensures that the following stages of the system can detect B lines more accurately.

C. Morphological Filtering

Morphological filtering is used to enhance specific structures present in the ultrasound image. This technique is useful for highlighting vertical patterns while reducing unwanted background information. By applying morphological operations, the system can emphasize the features that are related to B lines. This step improves the quality of the processed image and makes the detection of vertical artifacts easier.

D. Bottom Hat Transformation

The Bottom Hat transformation is an important image processing technique used to highlight bright vertical structures in the ultrasound image. It helps in enhancing the B line artifacts by removing background intensity variations. This operation improves the visibility of vertical lines that originate from the pleural line and extend downward in the image. As a result, B lines become more distinguishable from other image components.

E. Top Hat Transform

Top Hat transformation is an image processing technique used to highlight bright structures in an image. In lung ultrasound images, B-lines appear as thin bright vertical lines that start from the pleural line and extend downward. Sometimes these bright lines are difficult to see clearly because of uneven brightness and background patterns in the image. The Top Hat transformation helps by removing the background intensity and keeping only the small bright features. As a result, the bright vertical B-lines become more visible and easier to identify in the ultrasound image.

F. B Line Detection

In the final stage, the system detects the presence of B lines in the processed ultrasound image. The enhanced vertical artifacts obtained after Bottom Hat transformation are analyzed to identify B lines. These detected lines indicate the presence of lung abnormalities such as fluid accumulation or interstitial syndrome. The output of this stage helps medical professionals understand lung conditions and supports faster and more reliable diagnosis.

G. Gaussian Model

Gaussian model fitting is used to analyze pixel intensity patterns in the image. It fits the

data to a Gaussian curve to help detect important features like B-lines more accurately.

Abbreviations and Acronyms

All abbreviations and acronyms used in the paper should be defined when they first appear in the text. For example, Lung Ultrasound should be written first and later referred to as LUS. Similarly, B Line Detection System can be abbreviated as BLDS after the first definition. Once defined, the abbreviation can be used throughout the rest of the paper for simplicity and readability. Abbreviations should be avoided in section headings unless necessary.

Units

Standard units are used while describing the performance of the proposed B-line detection system. Image resolution is represented in pixels, and the ultrasound image intensity is represented as gray-scale values. Processing time of the algorithm is measured in seconds. These standard units help clearly represent the image processing operations and system performance.

4. Results

Following the completion of all of the processing steps that were performed on the image, we are now in a position to assert that the detection of B-lines in an ultrasound image of the lungs is both accurate and efficient. The most current processing resulted in a PSNR score of 98.0328, while the mean squared error was found to be 1.9672.

Following the processing of the ultrasound, the following images are presented:

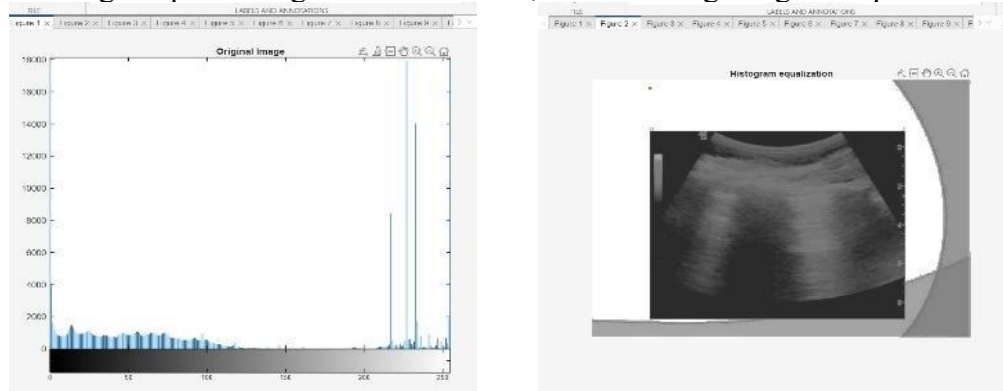
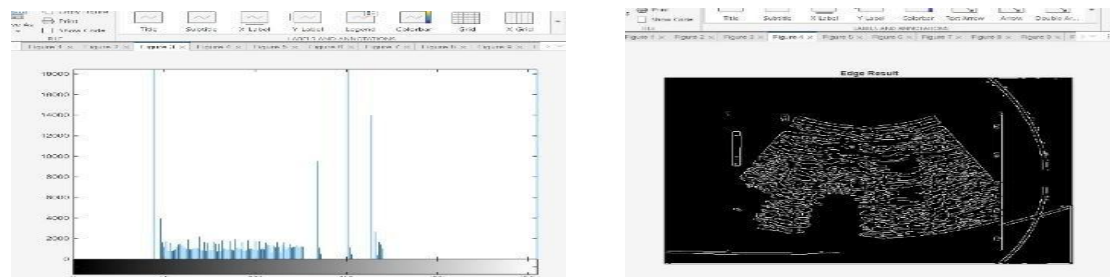


Figure 1:Input images with histogram



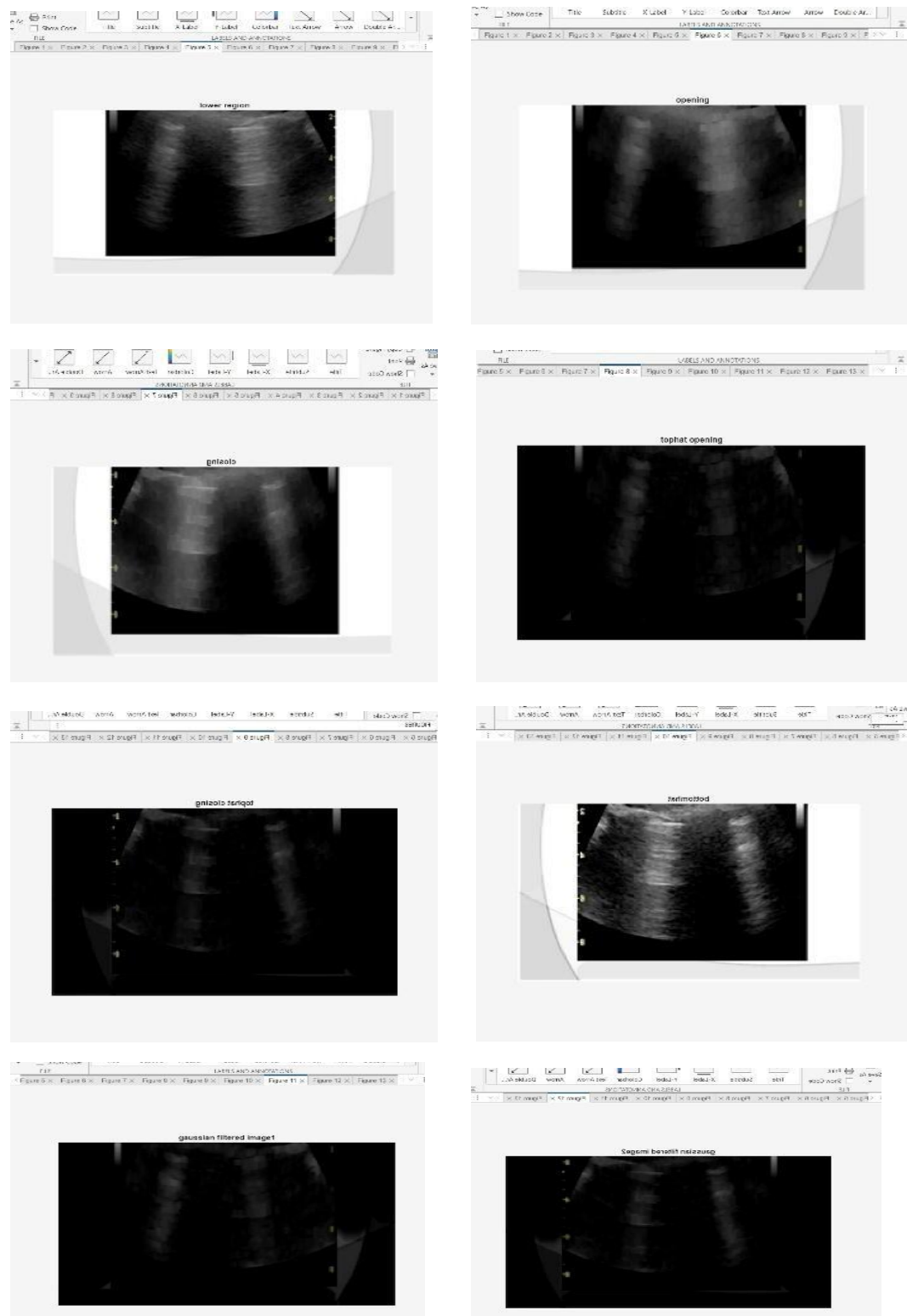


Figure 2:Proposed Method processing



Figure 3:Output image

5. Conclusion

This project presents an automated approach for detecting B-lines in lung ultrasound images to assist in the identification of pulmonary diseases. By using image processing techniques such as pleural line detection, noise reduction, and morphological bottom-hat transformation, the system effectively enhances and extracts B-line artifacts. The proposed method reduces manual dependency and improves consistency compared to traditional visual assessment by clinicians. The results show that the number and distribution of detected B-lines can reliably differentiate between healthy and diseased lung conditions. Overall, this work demonstrates a low-cost, radiation-free, and efficient solution that has strong potential for early diagnosis and point-of-care lung assessment.

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