Texture Analysis of Ultrasound Images for Pneumonia Detection in Pediatric Patients

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***Abstract*—Pneumonia is a condition that can be life-threatening and affects a high number of children around the world. Lung ultrasound can be used for the diagnosis of pneumonia, but requires high experience. This paper presents an approach for pneumonia detection based on texture analysis of ultrasound images. Several measures were taken in healthy tissues and pneumonia lesions, and the most significant features were identified by statistical analysis. The results of the analysis of variance and exploratory analysis suggest that detection of pneumonia is possible based on image texture features.**

***Index Terms*—Texture analysis, ultrasound imaging, pneumonia**

I. Introduction

Pneumonia is a lung infection that can be caused by viruses, bacteria or fungi. It can affect one or both lungs and happens when an infection produces the air sacs of the lungs or alveoli fill up with fluid or pus. It can make breathing harder because not enough oxygen enters the body to reach the bloodstream [1]. A critical aspect for the treatment of this disease is to make a timely diagnosis. Some techniques commonly used are x-rays, computational tomography, and ultrasound.

Generally, anyone can get this lung infection, but the disease commonly affects children under five years old. Some pneumonia symptoms often overlap with other common childhood diseases like malaria. According to statistics, pneumonia killed 920136 children in 2015, accounting for 16% of all deaths of children under five years old in the world [2; 3]. One of the possible causes of the high mortality is the lack of high quality health services, including appropriate diagnostic tools and trained personal, in remote and poor places. Therefore, there is a need for accurate and cost-effective tools to aid in the diagnosis of pneumonia and for automatic detection of lesions [4].

Ultrasound imaging is a cost-effective, portable and safe diagnostic method. These features give this technique an advantage with respect to computational tomography (CT) and x-rays, as ultrasound does not expose patients to ionizing radiation. In addition, several studies suggest that ultrasound may give comparable diagnostic accuracy respect to the aforementioned imaging techniques [5]. Claes et al. evaluated the performance of ultrasound to detect lung consolidations and obtained that sensitivity and specificity of ultrasound correspond to 98% and 92% PPV and NPV were 85% and 99%, respectively for pneumonia detection [6]. Cisneros Velarde et al. proposed a method for automatic pneumonia detection based on the analysis of the intensity and geometry of the pleural line in ultrasound videos [4]. Zenteno et al. proposed the use of power spectra measurements in the lung images for automatic pneumonia detection with good specificity [7].

In some cases, pneumonia has a similar appearance to other pathologies, such as bronchiolitis, in ultrasound images. Therefore, it is required high experience and skill from the doctors for an accurate diagnosis. Quantitative ultrasound allows to identify features in the images that can be used to identify pathological conditions [8].

This work proposes the analysis of texture in images of lungs with pneumonia lesions and healthy tissues, with the purpose of identifying quantitative measurements that may allow their classification.

II. Methodology

We propose an approach to analyze texture features of ultrasound images for pneumonia detection in children. Figure 1 shows a block diagram of the methodology. To develop this study, we followed the next procedure that was divided into three main stages: image acquisition, texture features extraction and analysis. For this study we did not use filtering to preprocess the images because it could affect texture features. The analysis stage is composed of two parts: analysis of variance (ANOVA) by using experimental design techniques (DOE) and principal components analysis (PCA). Image analysis for feature extraction was done in Matlab (Mathworks Inc.) and the analysis stage in RStudio (Version 1.1.442). Below there is a detailed description of each one of the stages.

A. Image Acquisition

We used ultrasound images from 20 pediatric patients previously acquired by a radiologist using a linear transducer. At least two images were acquired for each patient to analyze both lungs at different planes. The transducer was located in

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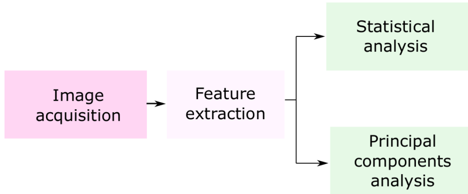

Fig. 1: Block diagram of the image processing stages

the space between the ribs to avoid acoustic shadowing. We selected a total of 29 images: 14 for pneumonia and 15 of healthy lung tissues.

B. Texture features extraction

For the diagnosis of pneumonia by lung ultrasound two features are considered: the continuity and brightness of the pleural line, and the presence of pus in the alveoli, which can be identified as a dark spots in the lungs. In this work, we focus on image texture analysis to identify the difference between images of healthy tissues and tissues with pneumonia. We selected a region of the image below the pleural line considering the differences in the texture of the image, as shown in Figure 2. If the image had pneumonia lesions marked by the doctor, the region selected was inside the lesions as shown in figure 3.

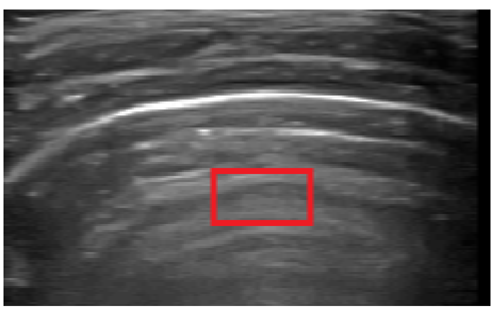

Fig. 2: Image of healthy patient image showing the selected region for analysis

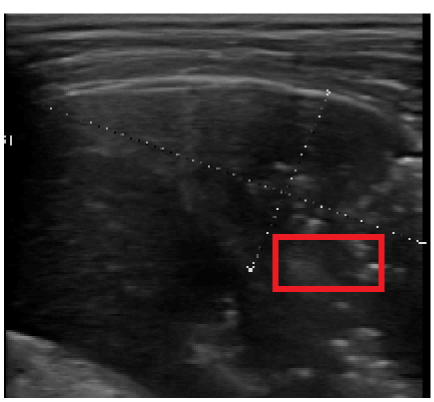

Fig. 3: Image of a patient with pneumonia showing the selected region for analysis

We computed the following measures in the selected regions of the images with the purpose of characterizing their texture:

1) Mean
2) Median
3) Variance
4) Kurtosis
5) Skewness
6) Standard deviation (Std)

III. Experimental design

We used a completely randomized experimental design (CRD) to assess the statistical significance of the subject's health condition from the texture features computed. In this technique, the total variance is composed of the treatments' and error's variability. While using CRD, only the treatment's variability can be controlled. The treatment in this study is the health condition. There are two levels of the treatment: pneumonia and healthy tissue and the design is balanced (14 images of healthy tissues and 14 with pneumonia). The hypothesis of this study is that the intensity of the pixels in each health condition will differ with respect to the mean levels in each response variable with a 95% of certainly.

IV. Results

A. Statistical analysis

The proposed statistical model was able to differentiate among the two health conditions: healthy and with pneumonia. After verifying that the assumptions of the model were satisfied, ANOVA was developed. Table I shows the ANOVA results only for the statistically significant features. Data marked with asterisk indicates $p - values < 0.05$. Only the mean and the median shows a difference statistically significant. The rest of the variables did not show a statistically significant difference.

Figure 4 illustrates the results using the least significant difference (LSD) test. It depicts the level plots for the two statistically significant features. We can state that it is possible to discriminate between healthy regions and regions with pneumonia by computing the mean and median of pixel intensity. It is clear that the behavior of these variables is quite similar, and the intensity of pixels is lower in the presence of pneumonia and higher for healthy tissues.

B. Exploratory analysis

From the use of PCA technique, an exploratory analysis was developed. Only the two first principal components (PCs) were selected as they represent the 74.3% the information. Figure 5 shows a visual representation of the individuals (subjects) and the variables in a new orthogonal space composed by the two PCs above mentioned. From this representation, it is clear that the majority of tissues with pneumonia are placed in the growing direction of the variance and in the opposite direction of growth of the mean, median and std. These last mentioned have a strong correlation and this can be proved in Figure 6, where the Pearson's coefficient value is presented for each

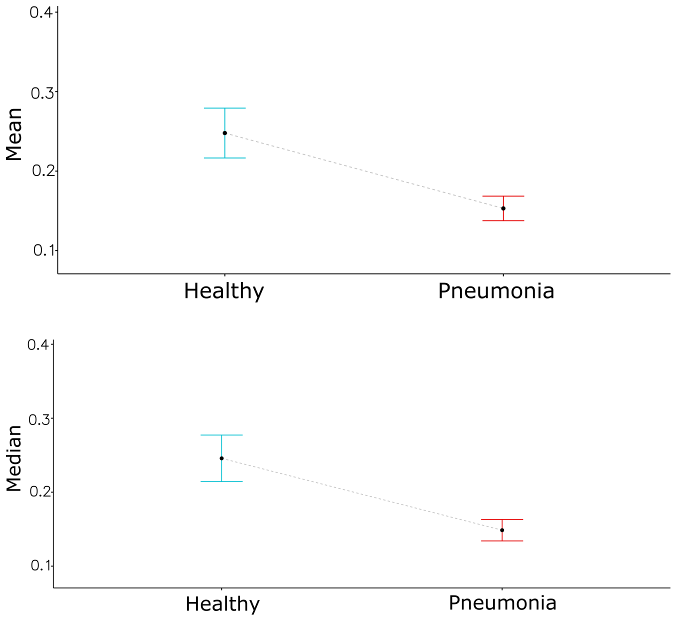

Fig. 4: Main levels of response variables for the health condition with LSD at 95% of certainly

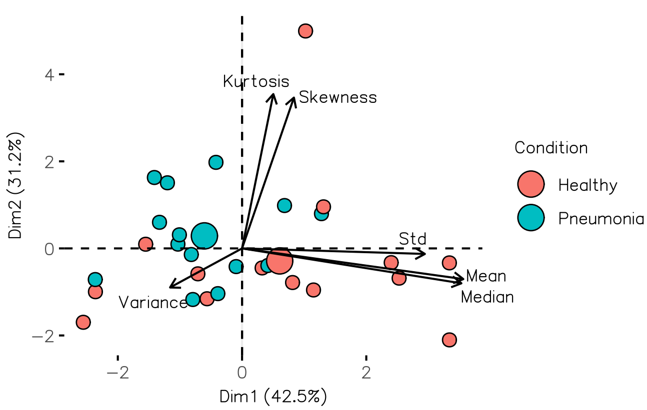

Fig. 5: Exploratory analysis based on principal components for pneumonia detection from the extracted features

pair of variables. The most intense color, the highest value of correlation and viceversa.

On the other hand, most of the patients with pneumonia are closely grouped on the second and third quadrant. Healthy patients are located on the other two quadrants. These patients are not grouped as close as those that have pneumonia. However, the tendency of patient with pneumonia are these whose mean and median intensity of pixels is low. The last listed fact can be proved with Figure 4. Eche et al. obtained similar results finding the mean as a significant criterion in the pneumonia detection [9].

Fig. 6: Correlation matrix visualization of the features extracted

Variable	*df*	*F*	η	*p*
Mean				
Health condition	1	6.3104	0.03608	0.01854*
Median				
Health condition	1	6.6267	0.03769	0.01609*

TABLE I: ANOVA results for the statistically significant variables

V. Conclusion

This work suggests that pneumonia detection is possible using texture analysis of ultrasound images. Differences at the mean levels were found in the mean and median. The pixels of images with pneumonia had lower intensity than the healthy ones. The results suggest that texture image processing of lung ultrasound can aid in the diagnosis of pneumonia in pediatric patients. However, it should be noted that pixel intensity is sensible to the scanner gain settings, firm placement of the transducer, and artifacts such as acoustic shadowing. Therefore, it is important to look for other metrics to better characterize tissues with pneumonia.

The next stage of this study is to use machine learning techniques for pneumonia classification including other features, such as intensity and shape of the pleural line, and more observations.

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