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Respiratory System Analysis System for Patient Care Against a Possible Risk of Tuberculosis

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ABSTRACT

According to the studies developed in advance, there is a crucial problem of doctors analysing computerised images of the chest visually, making a generalised diagnosis for their patients based on their experience, and making mistakes due to the different characteristics of each patient affected by bacteria in their respiratory tract. An infectious disease that has been increasing over the years is pulmonary tuberculosis, which has had around 12.7 million patients infected in 2020, with low-income countries being the main ones affected by this lung disease that is transmitted from person to person, so it cannot be based on the visual experience of the doctor, as this disease causes an increase of bacteria in the bloodstream and damages the alveoli, although there are various methods of detection, they do not provide a complete result on the patient's condition. The aim of this research is to develop a respiratory tract analysis system that will help doctors to detect tuberculosis earlier and more accurately and avoid prolonged infections that could be fatal for patients. The methodology used for this research is based on carrying out a computer analysis of the patient's chest and then carrying out image processing using MATLAB, using its various digital image processing techniques to detect these conditions. According to the system tests, it was observed that the system performs the detection of tuberculosis with an efficiency of 97.40% in its handling, standing out notoriously for its high value of efficiency, in addition to having the precise time for the determination of tuberculosis in the analysis of computerised images. In conclusion, this system can be used in different circumstances of the patient's condition, from the initial symptoms to an advanced stage of the patient's condition.

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1. Introduction

Pulmonary tuberculosis is a bacterial disease that has been present for many years worldwide [1], being the first fatal infectious disease that affected many patients in the world, surpassing HIV (human immunodeficiency virus) [2]. In 2020 an overwhelming event happened with COVID-19, which undoubtedly exceeded the number of patients affected by pulmonary tuberculosis due to the difficult situation experienced at that time [3]), to such an extent that it was announced as a pandemic by the World Health Organization (WHO) itself because it presented characteristics of high contagion [4], leading to its rapid spread around the world. To date, there are still patients sick with COVID-19, which since its appearance has marked a catastrophe in humanity [5], so the corresponding care should be taken to prevent catching this deadly virus.

The tuberculosis disease has had greater prominence especially in poorer countries, as well as in more disadvantaged areas of developed countries [6], which are no strangers to this disease where several cases of contagion were observed. According to data from the World Health Organization (WHO), about 12.7 million patients fell ill with pulmonary tuberculosis in 2020 and about 2.5 million patients died [7]. This disease of pulmonary tuberculosis is caused by the bacterium Mycobacterium tuberculosis, which is an etiological agent that produces tuberculosis infection in patients, transmitted from people to person by air [8], although it is a curable disease, it has been determined that a small proportion of patients with tuberculosis have developed the disease throughout their lives, maintaining constant treatment.

As specified by the World Health Organization (WHO), the main risk factors for pulmonary tuberculosis are due to malnutrition, excessive consumption of alcoholic beverages and cigarettes, as well as other diseases [9]. On the other hand, with pulmonary tuberculosis the bacteria increase in the bloodstream causing the lungs to become infected and damage the alveoli [10], which is why in order to detect and control this disease, doctors use various methodologies to effectively manage this bacterial disease, such as smear that detects the existence of bacilli (bacteria) within a biological sample, but it only detects certain cases of pulmonary tuberculosis because of their sensitivity [11]. We also have the sputum culture that detects the existence of bacteria that cause pulmonary tuberculosis infection, but it requires a lot of time to generate the results on the patient [12].

For this reason, one of the methods used by doctors on a continuous basis is the detection of tuberculosis by chest x-ray, which provides broader information on the irregularities of lung infections with greater sensitivity [13], but this method has errors in identifying several patients as false positives, identifying them with the bacterium Mycobacterium tuberculosis [14], for this reason, it was necessary to improve this methodology by applying a computerized technique to assist the doctor to detect a possible risk of tuberculosis early and with greater precision.

This research aims to cover the technological limitations that medical centres have for the detection of pulmonary tuberculosis in patients, as well as to displace the conventional form of evaluation of computerised images of the thorax where doctors use a visual evaluation to diagnose the condition of the respiratory system without security, which is why the importance of this system that will analyse patients with pulmonary tuberculosis, being able to avoid contagion and complications over the years.

The objective of this research work is to perform a system of analysis of the respiratory system for the care of the patient against a risk of tuberculosis, in such a way as to help doctors detect tuberculosis early in patients with greater accuracy and avoid prolonged infections that could be fatal for patients. To conduct the system, a computerized analysis of the patient's chest part must be conducted and then image processing must be conducted using MATLAB using various digital image processing techniques. MATLAB is a tool that allows you to perform various numerical calculations to analyse data through image processing.

In section II, the literature review of the research developed is conducted. In section III, the proposed system methodology is conducted using a block diagram. In section IV, image processing is conducted to detect risks of patients with tuberculosis. In section V, the results obtained from the proposed system are conducted. In section VI, the discussion of the proposed system versus other systems is conducted. Section VII provides the conclusion and recommendation of the proposed system.

2. Literature Review

Pulmonary tuberculosis, being a disease that is transmitted by air and directly, it is difficult to specify with certainty if a person may be infected with the tuberculosis bacteria, making it difficult for some people who can be infected inadvertently. Therefore, it is necessary that the doctor can determine any pathological variation in the respiratory system that may complicate the patient's health when using various systems. For example: In [15], the researchers mention that the detection of tuberculosis by means of a visual analysis of images of patients is difficult to determine with greater certainty pulmonary tuberculosis due to the different characteristics that each patient may present with the bacterium in their airways that may or may not be observed with the naked eye, Being able to cause the doctor in charge of evaluating the patient to determine the tuberculosis bacteria in an equivocal way in a healthy patient, therefore, they decided to develop a system of diagnosis of tuberculosis bacteria through images by means of an artificial network. The researchers' procedure is based on computerized images of patients that are analysed by means of an artificial intelligence method that will process the data more accurately to be able to determine and identify the different characteristics or lesions of the tuberculous bacteria in the respiratory tract of the patients, using an improved artificial network model that feeds back to the system for a more accurate detection. As a result, they presented a 92.31% efficiency in the diagnosis of lesions on patients with tuberculosis, concluding that the system diagnoses based on images of patients limiting them to direct contact.

In [16], the researchers mention that pulmonary tuberculosis is one of the problems that affects everyone and has a high rate of patients infected with this bacterium, likewise, not all medical centres have the appropriate diagnostic or treatment equipment for patients, applying the conventional method where they are based entirely on their experience, Being able to commit falsehoods with the prognosis of a patient and this can be dangerous to health, therefore, they decided to develop an intelligent system of diagnosis of pulmonary tuberculosis by the method of bacilloscopic. The researchers' procedure is based on the diagnosis of pulmonary tuberculosis through the ZN staining technique that is used to recognize pathologies such as tuberculosis bacteria, supported by an Arduino microcontroller, a small aluminium plate and various medical aid instruments that allow detecting the tuberculosis bacteria that are released into the air when a person with tuberculosis disease coughs or sneezes. As a result, they presented a 90.02% efficiency in the diagnosis of tuberculosis bacteria on patients, concluding that their system is good at diagnosing by smear, one of the methods most used by doctors.

In [17], the researchers mention that for a long time has been used as a tuberculosis detection tool, a computerized image analysis that according to the doctor's evaluation can determine whether or not the patient may have the tuberculosis bacteria in his lungs, but this verification of doctors has often had failures in its diagnosis, According to various studies almost 85% fail in the diagnosis of tuberculosis because they rely on their dexterity, therefore, they decided to develop an automatic system of nodules in computerized images using a concurrency matrix for the detection of pulmonary tuberculosis. The researchers' procedure is based on detecting the pathologies of tuberculosis through bacteria that attack the lungs, as well as other parts of the body. They also use the GLCM by analysing the components and vectors using an algorithm developed in Python, this algorithm will detect by means of sensors some features of the bacterium and based on this will determine its diagnosis on the patient. As a result, they presented a 91.77% efficiency in the diagnosis of the bacterium that causes pulmonary tuberculosis, concluding that their system classifies the intensity of the bacteria on the patient without problems according to the tests evaluated with some patients with tuberculosis.

In [18], the researchers mention that the tuberculosis bacterium is deadly for the lungs of those people who were infected, that for years they have tried to solve the question about the origin of it, as well as an effective treatment for this disease but this question has not been answered, causing doctors to continue treating this disease without relying on technology and based entirely on the practice they have had with Other patients, being able to make a mistake about the patient due to the little information they have, therefore decided to develop a tuberculosis prevention system applying fuzzy logic for asthmatic patients of the third age. The procedure of the researchers is based on using the input variable to the initial symptoms, then by means of the intermediate variable apply a filter according to what is specified by the system regarding tuberculosis to apply the fuzzy logic and determine if the patient has the bacteria in their lungs to perform a rapid treatment and prevent the patient from worsening with the disease or spreading the disease when infecting. to several people. As a result, they presented an 89.44% efficiency in the prevention of this disease, concluding that this system can prevent the patient from worsening their health, as well as the spread of this disease.

In [19], the researchers mention that tuberculosis is one of the contagious diseases, characterized by its high potential to cause death if you do not treat this disease in time, likewise, this disease has had various stages in patients that have made it possible or not to perform an effective treatment according to its progress. Although to date no systems have yet been developed to allow an accurate evaluation of the patient, the truth is that health professionals perform painful, expensive, and time-consuming tests to determine the evaluation of the patient, therefore, they decided to develop an automated tuberculosis detection system using pretrained CNNs and SVMs. The researchers' procedure is based on a system that can make decisions automatically according to the analysis of the computerized image of normal patients and patients with pulmonary tuberculosis reliably, first they applied several flood methods that allow analysing a set of data, then they applied a method of pre-trained networks so that they can extract similar characteristics and be able to classify patients by means of vectors. As a result, they presented a 93.99% efficiency with the correct decision making of normal patients and patients with tuberculosis, concluding that their system solves unknowns about the detection of tuberculosis, they also highlight that the methodology applied is complex, but helps to determine pulmonary tuberculosis.

3. Methodology

The methodology of the system is based on performing a punctual analysis of the respiratory system through images of the part of the thorax to apply image processing using MATLAB, being able to visualize pathologies that can cause a pulmonary disorder in patients. For the analysis of the system, it was prioritized that the process is broad and concise so that the doctor can rely on the result obtained, based on these characteristics a block diagram was elaborated where each process is specified, as well as observed in Figure 1.

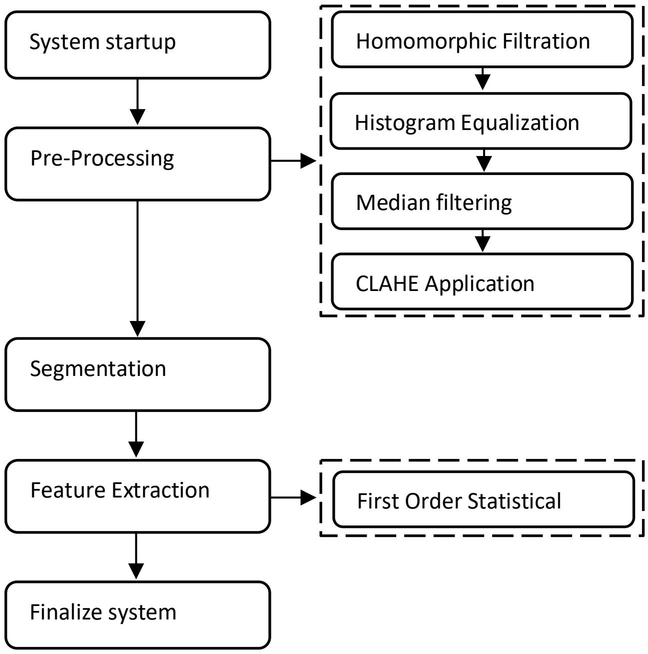


Fig. 1. Block diagram of the proposed system

3.1 Pre-Processing

The preprocessing of the computerized image of the part of the thorax is based on the application of various procedures that allow improving the characteristics of the initial image. When obtaining the computerized images, it is essential to perform a pre-processing to improve the stabilization of the image and prepare it to apply the image processing according to the needs of the system. The software used for image preprocessing is MATLAB, for its various tools that allow to improve the image and prepare it for image processing for a complete analysis.

The preprocessing consists of 4 parts, first a homomorphic filtration is applied to the computerized image of the chest part or that $f(x,y)$ allows to filter separately the luminance and reflectance $i(x,y)r(x,y)$ components of the computerized image that usually have non-uniform intensity properties, causing distortion at the edge of the ribs and obscuring the details [20]. Once the components are separated, we can filter the computerized image in the frequency domain by applying homomorphic filtering for image enhancement, as shown in Figure 2:

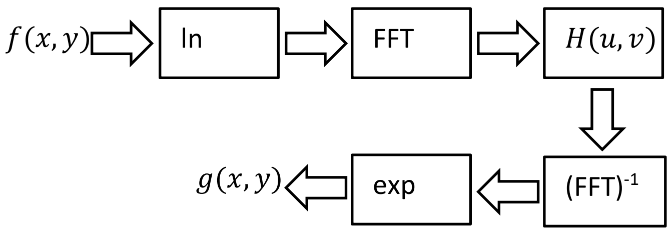


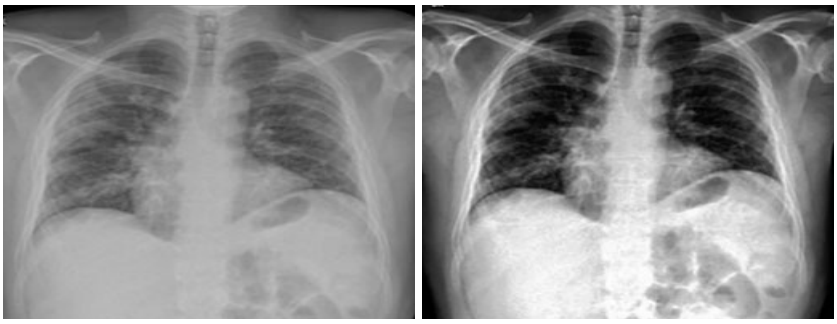
Fig. 2. Homomorphic filtering for image enhancement

The structure of the homomorphic filter: the logarithm transforms the product into a sum, allowing a linear separation of illumination and reflectance. According to the result of the linear filtering of the logarithmic image, we obtain the image filtered by exponentiation. Likewise, the advantage of image filtering by logarithm allows decomposing the filtering of the illumination and the reflectance separately, associating it at low frequencies with the lighting component, so that the homomorphic filter is usually a low pass filter, being able to recover the image through exponentiation.

The overall contrast of the computerized image is then improved by histogram equalization, allowing you to modify the intensity values so that the histogram of the output image matches the specified histogram. The histeq histogram equalization function attempts to match a flat histogram with 64 bins so that the pixel values of the output image are evenly distributed over the entire interval. To perform histogram equalization enhancement to the initial image obtained by computer analysis, the code shown below is applied to the grayscale image.

```
% Upload initial image
F = imread("pout.tif");
Figure
subplot (1,3,1)
imshow (F)
Subplot (1,3,2:3)
imhist (F,64)
%Histogram equalization function
P = histeq (F);
Figure
subplot (1,3,1)
imshow (P)
Subplot (1,3,2:3)
imhist (P,64)
```

Figure 3 shows that the original image has low contrast, with most pixel values in the centre of the intensity range. Then with the histogram equalization function it is adjusted, using the default behaviour with 64 bins of the histogram equalization function.



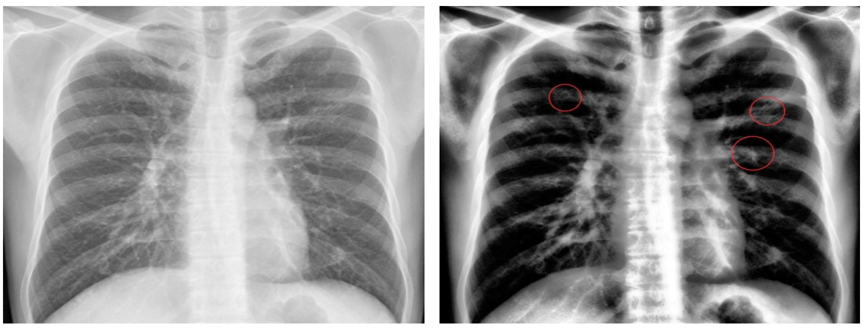
(a) (b)

Fig. 3. (a) Original grayscale image (b) Histogram equalization function

Then the median filter is used, allowing to have the advantage of median filtering that the final value of the pixel is the actual value present in the image instead of the average value, which reduces the blur effect of the filtered image. Likewise, the median filter (medfilt2) performs a nonlinear operation that is commonly used in image processing to reduce noise, being more effective when the objective is to reduce noise and maintain the edges at the same time. In parallel, a contrast-limited histogram adaptive equalization (CLAHE) is used with the adapthisteq function that operates on specific regions of the image called tiles, improving the contrast of the grayscale image to the point that the histogram of the output region matches the specified histogram, combining the contiguous tiles by using bilinear interpolation to eliminate artificially induced boundaries. To reduce noise with the median filter and improve local contrast with contrast-limited histogram adaptive equalization (CLAHE), the following code is applied to the grayscale image.

```
% Upload initial image
F = imread("pout.tif");
Figure
subplot(1,3,1)
imshow(F)
subplot(1,3,2:3)
imhist(F,64)
%Histogram equalization function
P = histeq(F);
Figure
subplot(1,3,1)
imshow(P)
subplot(1,3,2:3)
imhist(P,64)
%Median filtering
K = medfilt2(P);
imshowpair(F,K,'montage')
%CLAHE
J = adapthisteq(K);
Figure
subplot(1,2,1)
imshow(J)
subplot(1,2,2)
imhist(J,64)
```

As observed in Figure 4, section (a) shows the initial image in grayscales with little contrast and noise, while section (b) shows the image with better quality in contrast and clearly observing the nodules.



(a) (b)

Fig. 4. (a) Original grayscale image (b) Image enhanced by preprocessing

4. Image Processing

From the image processing part, the specified processes are explained to determine if the patient may present a risk of contracting tuberculosis. Once the preprocessing of the image was conducted, where the noise was reduced, the pixel values were levelled, and the contrast of the image was improved. You must continue performing image processing with the image segmentation process to divide the lung regions of the image, then continue with the extraction of features to finally perform the classification according to the values obtained from image processing.

The image processing part is comprised of 2 important processes, as mentioned in Figure 1, starting with the segmentation of the image, then with the extraction of features to finally classify the values. The selection of the patients analysed by this system was considered from the database of Hospital El Progreso, which consisted of 40 Posterior-Anterior (PA) computer images of the chest. There were 20 normal and 20 abnormal images of the patients, respectively, as test data. All images were resized to 1600 x 1600 to improve uniformity. Plain chest radiology is known as the process of capturing and evaluating a chest radiograph, previously taken by patients so that they can then be evaluated by the proposed system, which is why these images were considered from the hospital database.

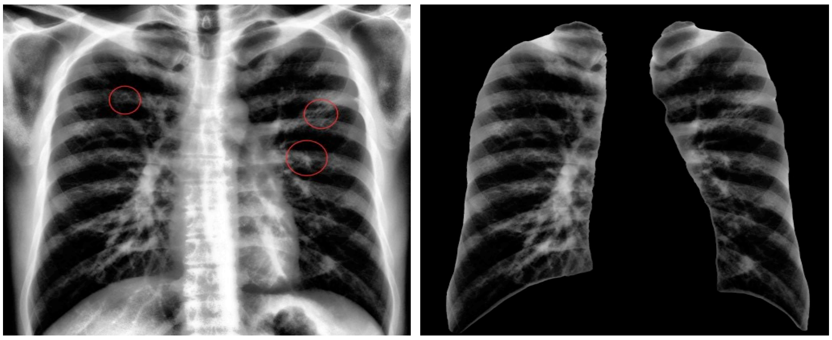
4.1 Segmentation

Image segmentation consists of dividing the image into specific parts or regions. Normally the division of regions is based on the characteristics of the pixels, that is, to detect regions within an image you must locate discontinuities in the pixel values, indicating the presence of edges, who define the regions. This process is done using the image segmenter tool, allowing to reduce or expand the predetermined lines of the segmented lung region with the shape of the lung.

The image segmenter tool is a repetitive process that segments the image of the chest and specifies the lung region, as shown in Figure 5, where all structures that are not part of the lungs are eliminated, relating them by the same intensity as the nodules. To segment the image and determine the lung region with the image segmenter tool, the code shown below is applied.

```
% Upload initial image
F = imread("pout.tif");
Figure
subplot(1,3,1)
imshow(F)
subplot(1,3,2:3)
imhist(F,64)
%Histogram equalization function
P = histeq(F);
Figure
subplot(1,3,1)
imshow(P)
subplot(1,3,2:3)
imhist(P,64)
%Median filtering
K = medfilt2(P);
imshowpair(F,K,'montage')
```

```
%CLAHE
J = adapthisteq(K);
Figure
subplot(1,2,1)
imshow(J)
subplot(1,2,2)
imhist(J,64)
%Image segmentation
imageSegmenter(J)
imshow(J)
```



(a) (b)

Fig. 5. (a) Pre-processed Image (b) Image segmented with lung region

4.2 Feature Extraction

The extraction of features is based on the criteria of first-order statistics obtained from segmented images of lung regions, characterized by their easy visualization based on the histogram of the image. Its most prominent features are: The average value indicates how dissociated the histogram is according to the intensity of the grayscale. The variance represents the modification of the histogram components between the grayscale intensity and the mean. Entropy represents the observed change in the shape of the analysed image. Dissymmetry is based on absolute slope. Kurtosis measures the greater or lesser concentration of data around the mean.

Then the classification process continues according to the criteria of the first-order statistics, managing to separate the analysed images into two conditions, healthy patients, and patients with tuberculosis bacteria. Likewise, the average value allowed us to differentiate the 2 conditions, considering it as a basis for the process of classification of the images. Table 1 shows the values of feature extraction.

According to the values displayed in Table 1, sick patients have a higher mean value, variance, and entropy unlike healthy patients. Indicating the value of the highest mean, the presence of more nodules in the lungs, as well as the high value of the variance.

Table 1
Extraction of characteristics from the assessment of healthy and sick patients

Characteristics	Healthy patients	Sick patients
The average value	19.3446	24.5429
Variance	1253.94	1621.44
Asymmetry	1.774	1.762
Kurtosis	3.522	3.213
Entropy	4.1864	4.4722

5. Results

With the development of the respiratory system analysis, the established objective of caring for the patient against a risk of tuberculosis is realized, in such a way as to support doctors to detect any pathology early and with greater precision, to prevent this disease from affecting the patient's health because it advances rapidly.

Table 2 shows the main characteristics of the respiratory system analysis, where the tools used for its correct functioning are determined, resulting in a benefit for the patient by determining a risk of tuberculosis that replaces the traditional method used in most hospitals and that are not dependable in the results they present.

As established in Table 2, the respiratory system analysis system detects tuberculosis with an efficiency of 97.40% in its management, standing out in a notorious way for the high value of its efficiency, in addition to having the precise time for the determination of tuberculosis in the analysis of computerized images of patients in the MATLAB software.

Table 2
Characteristics of the respiratory system analysis system

Analysis of the respiratory system	
Patient analysis	Computed radiography
Software	MATLAB
Body part analysed	Respiratory system
Operating time	30 minutes
Efficiency	97,40%

With the development of this system, the values that determine that a patient presents tuberculosis disease are identified with the high value of the mean, variance, and entropy, which indicate the presence of more nodules in the part of the lungs. Likewise, the operating time is essential for this system to determine tuberculosis disease more accurately.

For the implementation of this system, the software and the established parameters that are part of the system must be considered, being validated for its correct operation, which does not imply a high cost so it is completely accessible by any health centre that needs to implement it to apply it in patients with possible risk of tuberculosis and to be able to prevent or treat it in time.

The importance of conducting this system of analysis of the respiratory system against a risk of tuberculosis in patients, is that it contributes to the field of medicine, by not putting the patient or the doctor at risk since there is no direct contact between them at the time of evaluation. Making it important and novel it evaluates the patient.

To perform a correct operation, it is essential that the patient takes a computerized x-ray correctly and in advance, so that the system can perform a pre-processing and then apply the image processing and can classify according to the determined values to know if it is a healthy patient or patient with tuberculosis.

6. Discussion

There are several systems with independent methods that are oriented to the diagnosis of tuberculosis, likewise, there are several methods that doctors use based on their experience with this disease to face it and being able to make mistakes in their diagnosis. Although in both cases they seek to combat the disease, it is important to know more precisely the conditions of tuberculosis because the cases of patients with tuberculosis have increased.

In the same way, this system is based on a different methodology that allows diagnosing tuberculosis lesions that it aims to contribute in the field of medicine, therefore, it differs from several systems by the technique it applies to diagnose the lesions of the bacterium, for example, the research carried out by (Yang, Jin, and Li), where the researchers decided to route a diagnostic system of the tuberculosis bacteria through images through a network artificial. Obtaining as a result an efficiency of 92.31%, but this system when using an artificial intelligence method to process the data, did not perform an advance training before analysing the images of the patients, causing unreliable results with the detection of tuberculosis.

The research conducted by (Villarreal, Sanchez, and Soria), where the researchers decided to route an intelligent system of diagnosis of pulmonary tuberculosis by the method of smear. Obtaining as a result an efficiency of 90.02%, but this system has a limited functioning in the diagnosis of tuberculosis bacteria when using the method of smear due to the low sensitivity of detection, avoiding that it can fail in the diagnosis and complicating the health of patients.

The research conducted by (Junaedi, Yudaningtyas, and Rahmadwati), where researchers decided to route automatic nodule system into computerized images using a concurrency matrix for the detection of pulmonary tuberculosis. Obtaining as a result an efficiency of 91.77%, but this proposed system does not diagnose in a good way the bacterium that causes pulmonary tuberculosis, likewise, when analysing the images, it does not perform a preprocessing in advance to avoid errors in the analysis of the image.

The research conducted by (Meiah Ngafidin, Suryono, and Isnanto), where researchers decided to direct a tuberculosis prevention system by applying fuzzy logic for elderly asthmatic patients. Obtaining as a result an efficacy of 89.44%, but the tests conducted by the authors were not adequate, mainly because of the few patients who were evaluated with the system and the little specification regarding the progression of the tuberculosis disease that the patient could have.

The research conducted by (Oltu *et al.,*), where researchers decided to route an automated tuberculosis detection system using pretrained CNNs and SVMs. Obtaining as a result an efficiency of 93.99%, but this system is characterized by having a complex and difficult control for the doctor, likewise, it shows results of the analyses with few details of the disease, it simply detects tuberculosis and does not specify the advance, or the damages caused by this disease. Next, a comparison was made visualized in Table 3 of this system (a) with our system (b).

Table 3
Comparison between two detection systems, applying different methodologies

	a	b
Operation	Automatic	Automatic
Patient analysis	Photography	Computed radiography
Software	Not applicable	MATLAB
Body part analysed	Lungs	Respiratory system
Accuracy	93,99%	97,40%

7. Conclusion and Recommendation

From the perspective of the development of the system, it is concluded that its operating efficiency is extremely high, which helps doctors to detect a risk of tuberculosis in the patient to be able to treat it early and avoid future complications in the patient's health.

From the perspective of the development of the system, it is concluded that this system can be used in different circumstances of the patient's state, that is, when the patient feels the initial symptoms to determine if he has the bacteria in his lungs or if the patient is already with the bacteria to be able to know his state of health.

From the perspective of the development of the system, it is concluded that the system of analysis of the respiratory system for the care of the patient against a risk of tuberculosis is totally dependable for the doctors who control it and for the patient, since there is no direct contact between the two. Being important because this virus is transmitted through the air from person to person.

From the perspective of system development, it is concluded that an important tool for the system was image processing in MATLAB that allows to determine with greater certainty the presence of tuberculosis in the respiratory tract of patients. Although the programming language is of higher level, the algorithm that allows to determine tuberculosis was made in the best way.

From the perspective of the development of the system, it is concluded that its implementation is not expensive, facilitating various medical centres to be able to implement it due to the great benefit offered by this system such as analysis time and efficiency unlike other systems.

In the future, a database will be added to this system so that it can store the data of the patients analysed to be able to control the progression of their disease remotely and avoid any direct contact if it is not necessary.

The recommendation provided to the physician is to follow the recommendations of the system to take advantage of the correct operation of the system when analysing the computerized images of the patient.

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