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On the Development of a Novel approach for Lung Pathology Diagnosis based on Voice Processing using HMM

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ABSTRACT

The lung diseases have been examined through two ways: one is noninvasive process, which includes auscultation, pulmonary function test, respiratory inductance plethysmograph, and phonopneumography technique, and the other is invasive approach such as chest X-ray or roentgenogram and computerized tomography (CT) scan, and so forth. The invasive diagnostic procedures are expensive, time consuming, and harmful as in case of X-ray repetition.In this paper, weexplored anoninvasive technique for detecting theabnormal respiration in patients with respiratory pathology (asthma or tuberculosis). To achieve this target, we explained the main characteristics of these pathologies and their effect on patient life. We collected dataset from patient at hospital and other from interent. The main features were selected and classified by two eucledian distance and Hydden Markov Model (HMM). A friendly user interface were developed to help doctors in recording voice, respiration and caugth of paptient then process them on or off line. The user interface helps the doctor in diagnosis of the pathology based on recorede data. As a noninvasive toolsand based on simulation results, we can agree that the proposed design is an aide for doctors to take decision after a breaf consultation based on dialogue and breathing registrations.

Key words: Voice Processing; HMM Processing; Diagnoses Lung Disease

1. INTRODUCTION

Restricted lung disease is a very large group of diseases, and the common thing is a decrease in lung volume, as shown in Pulmonary Function Tests. These diseases are also called interstitial Tissue because they mainly affect the interstitial tissue in the lung. This label is misleading. In many cases, these diseases also affect the small bronchi and alveoli. Other uncommon diseases, such as sarcoidosis, primary pulmonary fibrosis, or immune system diseases such as lupus erythematosus, rheumatoid arthritis, scleroderma, In addition to multiple drugs, it may also lead to widespread pulmonary embolism and interstitial lung disease [4,5].

In some patients, the disease is severe, and symptoms persist only days or weeks, until the final diagnosis (mainly, diseases related to hypersensitivity or the immune system). In some patients, the disease becomes a permanent chronic disease, while the symptoms of the disease disappear in others, with or without treatment, or by avoiding exposure to the agent causing the disease (e.g. drugs). Another part of the patients is weeks and months before the diagnosis of the disease. In the remainder, the disease is chronic (months to years until diagnosis), and then the disease is known as chronic lung disease.Most interstitial pulmonary diseases are chronic and cannot be cured. The course of the disease is chronic, and the symptoms are exacerbated by chronic and advanced disease progression in the patient (acute on chronic). The health status of most patients is poor, they are restricted in their activities, and have low quality of life [6].
The most common symptoms that the patient is going to do to the doctor are: shortness of breath during a particular effort, worsening over time, chronic cough, improper analysis of chest X-ray, lung function analysis shows dysfunction of lung function and pulmonary symptoms in patients with disease In connective tissues.Common causes, which can be identified as causes of restrictive lung diseases, relate to the quality of work that involves exposure to organic or inorganic dust. Examples include Asbestos, silica, coal dust, cotton fiber, grain dust, mold, etc. Smoking, now or in the past, also contributes to the disease. Certain restricted lung diseases are more common among certain families. On the diagnosis level, the voice processing is considered an active field of research at the intersection of digital signal processing and symbolic language processing. Since the 1960s, it has benefited from very important research efforts related to the development of telecommunication resources techniques and new service of communication i.e. voice or IP and mobile phones.However, voice recognition and vocal tract processing are two most classical disciplines of speech processing. They continue to be, until today, a very attractive area for researchers [7].
Traditionally, the Lung pathologies diagnosis and treatmentare doneusing heavy material such as X-rays, ondoscopy and heavy therapy. Our choice fell on the treatment of the voice and acoustic signals not in the context of automatic speech recognition but rather in the perspective of identifying any pathologyin lung i.e.:

Asthma, tuberculosis or even lung cancer from just voice and breath signal processing , that is to say in other term recognition or diagnosis of a lung pathology from voice and breathing of patient, where an increase in the number of deaths due to respiratory diseases especially related to chronic obstructive pulmonary disease (COPD), lung cancer , tuberculosis (TB) and asthma can be expected.

In 2020, out of the 68 Million deaths in the world, 11.9 Million will be caused by lung diseases (4.7% by COPD, 2.5% by pneumonia, 2.4% by tuberculosis and 2.3% by lung cancer), in Algeria, annually 12% of new cases of asthma.On 2010, on the 11th edition of the Congress of the Maghreb Federation of respiratory diseases, stressed the urgency of the management of these diseases. Due to these death tolls alarming, this researchwork has been oriented on the developement of an assistant software for doctors to helpdiagnosis of asthma and tuberculosis in particular.The processing of speech and voice is the intersection of several disciplines; acoustics, phonetics, perception, linguistics, signal processing, programming, human-machine interaction, voice detection.There is an old proverb that states, "Life is in the breath. He who half breathes half lives."

If we have allergies, asthma or other breathing problems, this proverb may sound very familiar. But a greater understanding of patient breathing problems, along with an accurate medical diagnosis and effective treatment, can help them regain control. It does not matter what type of breathing problem they have. In this article, we explored speech signal processing techniques and automotic speech analysis or reconigion for the detection of respiratory pathology (asthma or tuberculosis). To argue the main reasons on which we base our work, we must give a definition of the processed speech signals (breathing and coughing) [10].

2. BREATHING AND COUGHING DISEASES

The spread of viral diseases that facilitate infection through human respiratory systems does not depend on geographical location, but on the nature of the place of residence or place of work, as well as on personal hygiene and public health; public spaces or overcrowded rooms transmit more and more rapid infection , And not to wash hands, or not to use tissue paper once, for example, makes many things that touch the focus of the presence of viruses, such as shaking hands, touching the door handles, and not cover the nose and mouth tissue paper when coughing or sneezing makes the spray loaded with the virus spread in more space, It is easy to prevent infection, lack of hygiene and spatial capacity in public facilities, which facilitates the spread of viral diseases. Therefore, any site, whether it is a village or a city, where the knowledge of people is so low, as stated by our true religion, Infectious, especially viral ones, transmitted by the usual social methods (such as hugging at the meeting) that some people do not care about.Common viral infections in the respiratory system include pharyngitis, larynx, people, bronchitis, pneumonia, as well as middle ear infections, sinuses, and tonsils. These viruses, or at least some of them, cause serious diseases that require intensive care, especially in children, and impose a significant physical and moral burden around the world. In the following subsections, we'll shed the light on the most familiar types of these diseases:-

2.1. Breathing

Breathing is the movement of the entire lung apparatus (including the diaphragm) that allows gases to enter and exit (oxygen and carbon dioxide) from the lungs. Respiration is based on the activity of the neurons in the reticular formation, itself in the medulla oblongata and the bridge, which are anatomical structures of nerves located in front of the cerebellum below the brain and above the spinal cord. There are many breathing problems like chronic or long-term. These common breathing problems include chronic sinusitis, allergies, and asthma. These problems can cause a host of symptoms such as nasal congestion, runny nose, itchy or watery eyes, chest congestion, cough, wheezing, labored breathing, and shallow breathing [11].

The medulla oblongata consists of clusters of nerve cells, specifically neurons, which play an essential role in breathing. This is the dorsal respiratory group containing neurons located at the dorsal portion (back) and at the cranial nerve root number IX and the ventral respiratory group. The ventral respiratory group consists of a network of neurons located on the ventral portion of the brainstem (forward) and extending from the spinal cord to the junction of the medulla oblongata and the bridge. The bridge, whose action is not precisely known with regard to the regulation of respiration, seems to soften the transition from inspiration to expiration and vice versa.The wheezing that characterizes the breathing of an asthmatic is called Sibilant rattle, it is the essential acoustics signal processed in our project.

2.2. The Coughing

The cough can be defined as an act performed by a person to get rid of what is stuck in the throat or respiratory passages, such as microbes, mucus, irritants, lingering liquids, etc. The cough can be voluntary or involuntary. In fact, it is often mild and goes away within a few days, but there are some cases where the cough indicates a serious health problem. Although there is a possibility of coughing at any time of day, there are some cases where the patient is coughing during the night more. The second stage is the closure of the vocal cords and increase pressure in the lungs and throat, and finally the third phase expresses the exit of air after opening the vocal cords and the exit of the sound accompanying the cough as it is known, It should be noted that the cough causes discomfort to the patient and the discomfort, and the patient must see the doctor if the specialist continued cough for three weeks or more, and if cough increased worse, and if the blood in the cough, or chest pain, or difficulty in Breathing, or Accompany the fever to cough without improvement, or difficulty swallowing, or weight loss, and other unusual symptoms. The cough is a sudden and noisy exhalation, reflex or voluntary, ensuring the expulsion of the air (the speed of expulsion can reach 900 km / h) contained in the lungs, it is a reaction of the body to irritation, it is a vital reflex.Cough is somehow unavoidable allowing the expulsion of undesirable substances (dust, foreign bodies) or is the expression of a serious disease, however cough is not a disease but is the symptom of other diseases or infections.

The cough can be categorized as acute, acute, and chronic cough. Acute perspiration lasts for up to three weeks. Acute coughing lasts for three to eight weeks, while coughs

lasting more than eight weeks are called chronic cough. There are a number of reasons for coughing, including viral or bacterial infections such as common cold and influenza: Flu, which is a type of upper respiratory infection, atypical Infections. Most cases of infection are caused by a viral infection, usually cured alone. In some upper respiratory tract infections, however, the causative agent may be one of the bacteria, which in most cases requires the release of antibiotics; In addition, there are other types of bacterial infections that may cause cough, such as whooping cough, croup, and pneumonia. Smoking: Smokers suffer from chronic cough, and coughing is usually characterized by a distinctive voice. Asthma sufferers suffer from wheezing, asthma often occurs in children, and children can recover from asthma when they reach and age. However, it is important to note that there are asthma attacks, and then appropriate sprays must be taken. Some types of drugs can cause the person to suffer from cough as a side effect. These drugs are commonly known as angiotensin-converting enzyme inhibitors, but coughs are rare side effects. It soon disappears when you stop taking the medicine [12,13]. Chronic bronchitis: chronic bronchitis. This condition is chronic. It is associated with the patient for the duration of his life, usually because of smoking or exposure to certain contaminated industrial materials. The principle of treating this condition depends on the distance from the bronchial irritants and may stop smoking, and may resort to the specialist doctor to dispense some of the sprays containing corticosteroids, as well as spend for long-term bronchodilators or impact. Other diseases: In addition to the above, there are a number of health conditions that cause the person suffering from cough, including the following: damage to the vocal cords or damage in general. Post-nasal drip. Pulmonary embolism. Heart failure. Gastro esophageal reflux disease.

2.3 Asthma: Asthma is a common, chronic disease occurring at any age, characterized by inflammation and narrowing of the airways. The narrowing is intermittent in moderate asthma but becomes persistent very frequently. Symptoms can change very quickly, either spontaneously or following treatment. It belongs to the field of obstructive bronchopulmonary diseases and is characterized by reversible bronchial obstruction and bronchial hyperreactivity, but the clinical features and response to treatment are variable. These phenotypes represent the visible effects of the interaction between the genetic base of the individual and his environment.Asthma is a common and chronic disease of the respiratory system that reaches millions of people around the world. Because of its high prevalence, morbidity, mortality and its socio-economic cost, this disease is increasing and thus poses a serious public health problem. Indeed, notwithstanding the spectacular advances, includingnew and effective therapies, the number of people with asthma continues to grow especially with urbanization and change in lifestyle. Moreover, if we considers that the urban population in 2009 exceeds 50% of the world's population (to reach 3.3 billion city dwellers) and that the projection in 2025 will be more than 77% (about 5 billion people living in urban areas) [2], it is estimated that 100 million additional asthmatics could be expected by 2025 [3] . The extent of the disease international level is such that the World Health Organization (WHO) has qualified 2008 "global emergency", after an epidemiological study whose results concluded that acute respiratory infections, and in particular asthma, are responsible for 70% recorded deaths in sub-Saharan Africa and South-East Asia among children of less than 5 years old.

2.4 Tuberculosis: Pulmonary tuberculosis is an infectious disease of the lung but also of the pleura: that is to say membranes covering and protecting the lungs. This condition is the result of the penetration of the bacillus of Koch also called BK where Mycobacterium tuberculosis. Its contagiousness or, if one prefers, its transmission, is relatively weak.Contamination occurs mainly by air at the time of repeated contact with an individual who is not immune: that is, who has no natural defense against the disease.For a patient who rejects, meanwhile, bacilli in the air he exhales (coming out of the lungs), we speak in this case bacillifère subject. It is an infection that is either acute (relatively short) or chronic (spread over a long period) [14].

3.TUBERCULOSIS STATISTICS IN ALGERIA

An untreated TB patient can infect an average of 10 to 15 people each year. Population displacements (travelers, war refugees, homeless people in industrialized countries) have made a major contribution over the last 40 years to the spread of the disease on the planet. Every second, a new person in the world is infected with Koch's bacillus. Every year, nearly 1% of the world's population is newly infected and about 8 million people develop the disease. Globally today, one third of the world's population is infected, and 22 countries alone account for 80% of global cases.
More than 2 million annual cases of tuberculosis occur in sub-Saharan Africa. This figure is rising rapidly because of the AIDS epidemic that is particularly affecting this region of the world. Nearly 3 million annual cases of tuberculosis are reported in Southeast Asia. More than 250,000 of the annual cases occur in Eastern Europe.In Algeria, 20,000 new cases are registered each year, and each case costs the public fund 50,000 DA.Over the world, more than 9 millions are affected with tuberculosis and around 2 Milliondead each year [1].

Distribution by sex:The overall distribution of TB cases by sex shows a slight predominance for the male sex with a sex ratio of 1.05 (51.3% of cases in men). But with variations depending on whether one is interested in pulmonary or extra-pulmonary tuberculosis. This is can be explained mainly by smoking cigarettes.

4.PROCESS OF AUTOMATIC DETECTION OF RESPIRATORY DISEASE

The process of automatic detection of the disease from the analysis of breathing or cough can be broken down into three main parts:
a- Pretreatment of breath signal or cough.
b- The extraction of the characteristic parameters the breathing of the patient.
c- The decision module which makes it possible to recognize the pathological case of the patient to test.

Regarding the Pretreatment of the breath signal:A pretreatment of a voice signal is performed in two steps: Acquisition and Windowing as shown in Fig.1 where each step will be described as follows:-

4.1-Acquisition

To be usable by a computer, a signal first must be digitized. This operation tends to transform an analog temporal phenomenon (the sound signal in our case) into a series of discrete elements, the samples. These are obtained with a specialized map common today in computers since the advent of multimedia. The sound digitization is based on two parameters, the quantization and the sampling frequency.

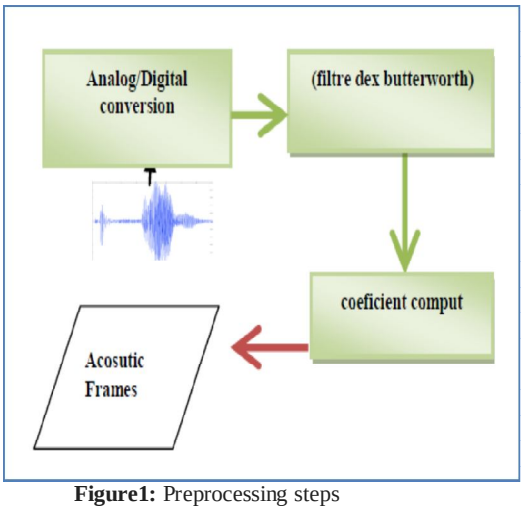

Figure1: Preprocessing steps

Quantization defines the number of bits on which to scan. It measures the amplitude of the sound wave at each step of the sampling. Moreover, this quantification can follow a linear or logarithmic scale, the latter favoring the resolution of the quantization for the weak levels to the detriment of the strong levels.The choice of the sampling frequency is also decisive for the definition of the bandwidth represented in the digitized signal. Shannon's theorem tells us that the maximum frequency fmax present in a sampled signal at a frequency ***fe*** is equal to half of ***fe***. A signal sampled at 16000 HZ therefore contains a frequency band ranging from 0 to 8000 HZ. According to this principle, it is therefore useless to digitize a telephone signal to more than 68000 HZ, because the result would not contain more frequency information. However, since the majority of cards offer only certain acquisition frequencies, the telephone signal is generally sampled at a frequency of 8000 HZ, which also makes it easier to define frequency filters [15,17].

b) Butterworth filter: A Butterworth filter is a type of linear filter model, designed to have a gain as constant as possible in its bandwidth.

The main characteristics of this filter is given as follows: The gain of a Butterworth filter is as constant as possible in the bandwidth and tends to 0 in the cutoff band. On a logarithmic Bode diagram, this response decreases linearly to -∞, -6 dB / octave (-20db / decade) for a first-order filter, -12db / octave or -40dB / decade for a second-order filter, -18dB / octave is -60dB / decade for a third-order filter, and so on.

4.2.Data set Description

Our database contains vectors of voice recordings, the two sexes (male female) and two average ages (adult, child) were taken into account. The number of registred persons is 80 patient from'Dorban Hospital' In Annaba city. The collected files contain: 40 patients infected with TB, 25 with severe Asthma, 15other pulmonary problems; we also collected from university 30 files for sain persons [3].For each patient or person, we have taken two files: one where we registred a discussion of 10 min with him and the second just breathing and caughing of the subject for 5 mn. Thus we have 110*15mn of registered data.These recordings of type wave (file.wav), are taken using a microphone connected to lap top with processor I3 and 1.6 GHz frequence and 2 Gbyte of RAM, we used the recording interface of Windows.

4.3.Processing Data

a) Training phase:

The learning phase consists of parameterizing the voice recordings of the (respiratory) database of type (. Wav) into reference vectors of type (.mat), this is done in three steps:
1- Load the records for each patient of the same disease and extract the parameters (T, PPZ, En, F0, F1 and F2) to convert them to vectors.
2-Comput average of all vector for a patient with pathology to have a vector mean for each patient. 3- Average its last to have a single reference vector for each pathological case.

4.4-Principle of Proposed Model Operation System

The process of automatic diagnosis of pathology can be broken down into four main stages:
a- Recording of breathing or coughing.
b- Preprocessing of the signal of breathing or coughing.
c- Extraction of the characteristic parameters of the recording.
d- The recognition and classification which make it possible to know the pathological case of the patient.

4.4.1-Voice recording step

The recording of the patient's breathing or coughing to be tested, using a voice-recording instrument such as the microphone, where the recording is a file of type (.wav).

4.4.2-Preprocessing and parameterization steps

If the first two stages are dismayed, their principle is discussed in the third section, i.e., the automatic selection of the segments of the respiratory signals (exhalation, inspiration) or coughing. Its information-bearing segments allow the calculation of the average of the parameters (the duration T, the number of zero crossings PPZ, the energy En, the fundamental F0, and the formants F1, F2) of its segments to have the vector recording to be tested.

4.4.3- Recognition stage

As regards the recognition phase, an iterative algorithm searches for the reference vector, which is the closest to the recording vector to be recognized by the method of calculating the Euclidean distance between the vectors.So

in summary the voice signal emitted by the patient, once set, will be compared to the vectors of the reference dictionary (recognition phase). The recognition algorithm makes it possible to choose the vector of the most resembling pathology, by calculating the rate of similarity in the sense of a distance to be defined between the vector of the tested patient and the various references, the program will compare the vector of recording to test with those who are in memory since the learning phase, depending on the result of this comparison, we can mathematically decide which record and the most similar.

4.4.4. EuclideanDistance

Based on features of the three main classes we would like to recognize (Asthma, Tuberculosisi and Sain), we computer a vector main for each class.However, if we want to talk about the distance between two parameter vectors, it is necessary to have an identical dimension. The vector distance to be tested can be calculated from the reference set. In this case, the Euclidean distance is used:

$$d(x, y) = \sqrt{\sum_{i=1}^{d} (x_i - y_i)^2} \quad (1)$$

Where:

d: The distance between two vectors x and y

x_i and y_j : Elements of vectors x and y respectively

4.4.5.HMMClassifier

In hidden Markov models, the concept of a state sequence that is modeled statistically as augmented with state-specific outputs of the model. The underlying state sequence is hidden—a fact from which the name of this model variant is derived. In order to make the evaluation of such models tractable, strong limitations apply for the statistical regularities which underlie the generation of the state sequence and the outputs of the model. In general, a hidden Markov model can be regarded as a finite-state automaton with outputs which is augmented statistically. Both the transitions between states and the generation of outputs occur depending on certain probability distributions [16].

The most important parametric distribution in the context of Markov models and maybe even beyond is the normal distribution, which is defined for continuous random variables only. For a univariate random variable satisfying a normal distribution, one obtains the following probability density function.

Features extraction: we selected to extract main and classic feafures used in sppech processing technique swe have already done in [8] and [9], fundamental frequency (F0), zero crossing (ZC), maxi/min numbers (T), Energy (En) and formant 1 and 2(F1, F2).

Here is the specrum of three siganls from dataset where the first one is with tubercolosis, the second with Asthma crisis and thethird sain, it is clear that there is a difference in figures thus taking F0,F1,F2, Energy and ZC.

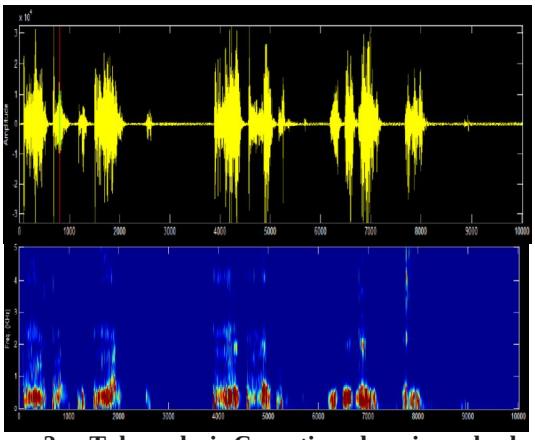

Figure 2.a :Tuberculosis Case: time domain and colored spectrum

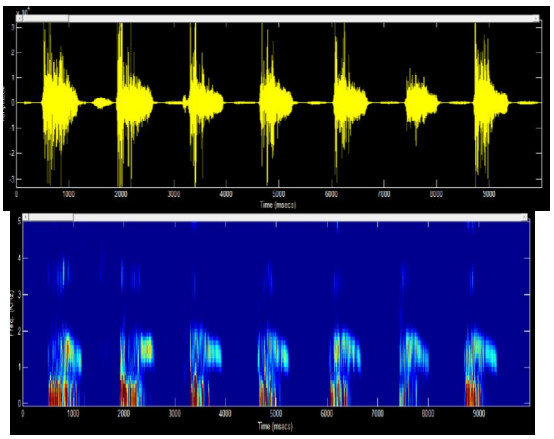

Figure 2.b : Asthma Case: time domain and colored spectrum

Decision or classification:

After calculating the distances between the recording vector of the patient to be tested and the three reference vectors for pathological cases, in determining the minimum distance of the calculated distances, and the discision will be applied to it.The display of the discision will be through a graph user interface, which will be defined later.

5.INTERFACE AND OPERATION

In order to make our diagnostic system available to the user (e.g. Doctor, Speech pathologists, attending physician and nurse) and easy to manipulate, we use a graphic user interface (GUI) in which:-

- For recording new respiratory signal.
- Execution of the process of treatment and discision.
- LED indicator of respiratory pathology detection in RED color if sain then the corresponding Led is Green.
- For the diagnosis, it suffices to click on the "treatment" button in order to apply the parametrization and recognition program.

- The doctor can register the respiration and coughing sounds from discusion with a patient, then he can process the audio signals off line.

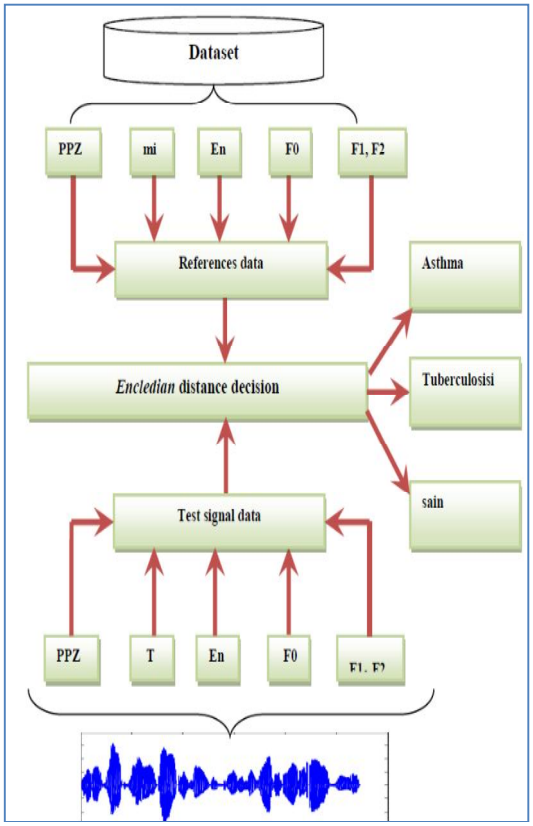

Figure 3: Principe of the proposed model operation

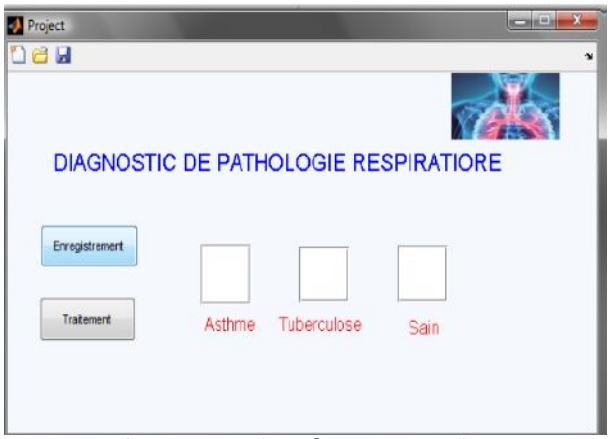

Figure 4: GU-interface presentation

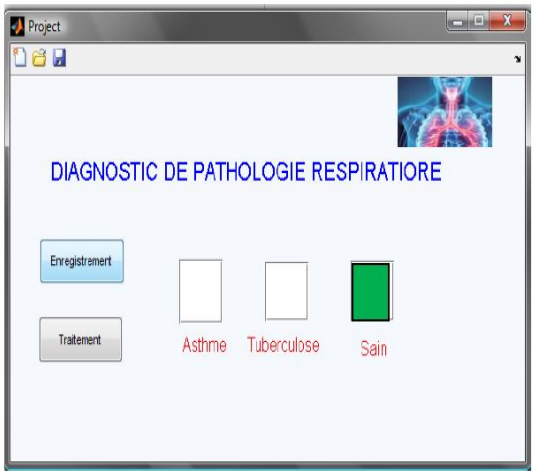

Figure 5: Test results on the GUI

a) Case of Asthma detection,
b) Case of Sain person,
c) Case of Tuberculosis detection

6.TEST RESULTS TABLE

We have tested the proposed model off line using the collected dataset where we have selected some files for test and the results were registered on table 1, whichshows a simple test of reliability of our diagnostic process carried out from the recognition tests on 100 patients of each pathological case.To improve the results, we used also

SVM linear classifier by taking the same number of signals for training and testing, the obtained results were presented on table 2.

Table 1: Results based on Euclidian distance

Case of Pathology type	*Asthmatic*	*Tuberculosis*	*Sain*
Asthmatic	59%	7%	34%
tuberculosis	31%	43%	26%
Sain	13%	9%	78%

Table 2. SVM results or HMM classifier

Case of pathology type	*Asthmatic*	*tuberculosis*	*Sain*
Asthmatic	59%	7%	34%
tuberculosis	31%	43%	26%
Sain	13%	9%	78%

7.CONCLUSION

Speech or voice processing is a vast and rich field for scientific research. In this work, we intend to detect or diagnosis respiratory pathologies by sound voice processing. Due to evolution of tuberculosis and asthma in our region and especially in Algeria, we found that it would be interesting to develop a software application to aide in precauce detection of the pathologies.The techniques used in our work are the most classical techniques and the most used in the field of automatique speech recognition methods. Where we need a data set, features extraction and classification technics.

Since each pathological case is characterized by symptoms which are the essential criteria on which one chooses the ideal parameters for the diagnosis, as well as there are other symptoms that have not been taken in our process that is to say that we has an infinity of symptoms characterized each pathological case, and that we can consider them as criteria of choice of the reference parameters.

The reliability of our process depends on the symptom criteria chosen for the measurement, as well as the instruments used for the recording and the environment where the recording is done.

The asthma and tuberculosis selected in our work as a result of statistics that shows the enormous threat to the population in the world and in Algeria particularly, because of pollution and lack of means to fight epidemics.In point of sociological view. We conclude also that, from technical point of view, the detection of illnesses in medicine relies much more on the treatment of the patient's breathing or cough, in addition, we conclude that sex and age has on effect on detected cases contrary to speech recognition where age and sex can make difference.The obtained results on both datasets show small difference;also,the second classifier gave better results.

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