Effective Analysis and Diagnosis of Respiratory Tract Infection Diseases: A Review

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Abstract: **Human Respiratory System is the breath of Human body. The respiratory tract infection diseases are found increasingly affecting the human body and a huge population is reported to be suffering from these diseases. An improvement in the conventional methods for Analysis and Diagnosis of Respiratory Tract Infection Diseases is a must. The present paper briefs about the respiratory system, the common respiratory tract infection diseases and proposes the effective analysis and Diagnosis tools.**

Keywords: **Respiratory tract, Infection diseases, Fourier transform, wavelet transform, Genetic algorithm, Neural Network, Fuzzy Logic**

I. INTRODUCTION

Researches in biomedical Engineering have emerged with effective tools for the study, analysis and diagnosis of Human Anatomy and associated disorders. Huge amount of research focuses on the analysis and diagnosis of Respiratory tract Infection Diseases.

The Respiratory tract is divided as upper respiratory tract and lower respiratory tract. The upper respiratory tract includes Nose, Ethmoidal air cells, Frontal Sinuses, Maxillary sinus, Sphenoidal Sinus and Larynx. The lower respiratory tract includes the Trachea, Lungs, Air ways {bronchi and bronchioles) and the air sacs (alveoli). Together with all these organs the respiratory tract is responsible to give the breath that keeps a Human alive.

According to American Lung Association, almost 400,000 people die from Lung disease each year [1]. Lung Disease is the third leading cause of death in the U.S. Lung disease and other breathing problems are leading causes of death in infants. Major Respiratory tract infection diseases include Chronic Obstructive Pulmonary Disease (COPD),

Asthma, Restrictive lung diseases, Respiratory tract infections Upper respiratory tract infection, Lower respiratory tract infection, malignant tumors. The major types of respiratory system cancer are: Lung cancers, Neck and Head cancer.

Methods for analysis and diagnosis of the respiratory tract infection diseases are based on two parameters viz. respiratory sound and respiratory tract imaging. Over the last four decades, researchers have made significant progress in fine-tuning computerized signal processing techniques, and it is now possible to perform respiratory sound analysis using many of these techniques [2],[3]. Imaging involves investigations by chest X Rays, Computer tomography (CT) Scan, Bronchoscopy, Biopsy of the lung or pleura, Ventilation-Perfusion Scan, etc. A host of computer analysis techniques has been applied to CT images of the lung [4]. Modern Mathematical tools like Fourier Transforms, wavelet Transforms, Artificial Neural Network (ANN) and the Fuzz Logic enhance the early detection & diagnosis.

The Paper is organized to briefly explain the Anatomy of Human Respiratory system, the major respiratory tract diseases, discuses the Modern Analysis and Diagnosis Tools, highlights the research work in the field and finally proposes the neuro -fuzzy approach as an optimized tool.

II. HUMAN RESPIRATORY SYSTEM

Respiration:

Respiration is the act of breathing:

- Inhaling (inspiration)--taking in oxygen
- Exhaling (expiration)--giving off carbon dioxide

The respiratory system

The respiratory system (fig. 1) (or ventilator system) is the biological system that introduces respiratory gases to the interior and performs gas exchange. The respiratory system is made up of the organs involved in the interchanges of gases, and consists of the:

- Nose
- Mouth (oral cavity)
- Pharynx (throat)
- Larynx (voice box)
- Trachea (windpipe)
- Bronchi
- Lungs

The upper respiratory tract includes the:

- Nose
- Nasal cavity
- Ethmoidal air cells
- Frontal sinuses
- Maxillary sinus
- Sphenoidal sinus
- Larynx

The lower respiratory tract includes the:

- Trachea
- Lungs
- Airways (bronchi and bronchioles)
- Air sacs (alveoli)

The exchange process occurs in the alveolar region of the lungs.

Functions of the lungs

The lungs take in oxygen, which the body's cells need to live and carry out their normal functions. The lungs also get rid of carbon dioxide, a waste product of the cells.

The lungs are a pair of cone-shaped organs made up of spongy, pinkish-gray tissue. They take up most of the space in the chest, or the thorax (the part of the body between the base of the neck and diaphragm).

The lungs are enveloped in a membrane called the pleura.

The lungs are separated from each other by the mediastinum, an area that contains the following:

- Heart and its large vessels
- Tachea (windpipe)
- Esophagus
- Thymus
- Lymph nodes

The right lung has three sections, called lobes. The left lung has two lobes. When you breathe, the air:

- Enters the body through the nose or the mouth
- Travels down the throat through the larynx (voice box) and trachea (windpipe)
- Goes into the lungs through tubes called main-stem bronchi
    - One main-stem bronchus leads to the right lung and one to the left lung
    - In the lungs, the main-stem bronchi divide into smaller bronchi
    - And then into even smaller tubes called bronchioles
    - Bronchioles end in tiny air sacs called alveoli

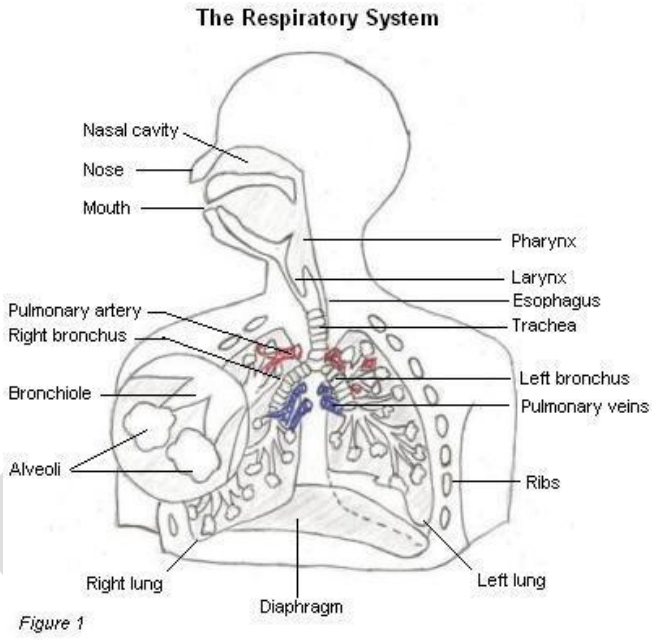

Figure 1. The Respiratory System

III. MAJOR RESPIRATORY TRACT INFECTION DISEASES

Respiratory disorders are now the number three cause of deaths around the globe. More than 400 million people suffer from respiratory disorders mainly like COPD, asthma, etc.[7] Respiratory disorders span from the mild common cold to serious conditions like asthma and COPD. These widely prevalent conditions pose a major healthcare challenge. Major Respiratory diseases are as follows[8]:

- Chronic Obstructive Pulmonary Disease (COPD)
- Asthma
- Restrictive lung diseases
- Respiratory tract infections
- Upper respiratory tract infection
- Lower respiratory tract infection
- Malignant tumors
- The major types of respiratory system cancer are:
    Lung cancers
    Neck and Head cancer

Chronic Obstructive Pulmonary Disease (COPD)

Chronic Obstructive Pulmonary Disease (COPD), an example of an obstrutive lung disease, is where the airways become damaged, causing them to narrow.

Asthma

Asthma is another example of an obstructive lung disease, (and of an inflammatory lung disease).

Restrictive lung diseases

Restrictive lung diseases (also known as interstitial lung diseases) are a category of respiratory disease characterized by a loss of lung compliance, causing incomplete lung expansion and increased lung stiffness. E.g. in infant respiratory distress syndrome (IRDS).

Respiratory tract infections

Infections can affect any part of the respiratory system. They are traditionally divided into upper respiratory tract infections and lower respiratory tract infections.

Upper respiratory tract infection

The most common upper respiratory tract infection is the common cold however, infections of specific organs of the upper respiratory tract such as sinusitis, tonsillitis, otitis media, pharyngitis and laryngitis are also considered upper respiratory tract infections.

Lower respiratory tract infection

The most common lower respiratory tract infection in is pneumonia, a lung infection. Pneumonia is usually caused by bacteria, particularly Streptococcus pneumonia in Western countries. Worldwide, tuberculosis is an important cause of pneumonia. Other pathogens such as viruses and fungi can cause pneumonia for example severe acute respiratory syndrome and pneumocystis pneumonia. A pneumonia may develop complications such as a lung abscess, a round cavity in the lung caused by the infection, or may spread to the pleural cavity.

Respiratory tumours

Tumours of the respiratory system are either malignant or benign.

Malignant tumours

Malignant tumours, or cancers of the respiratory system, particularly lung cancers, are a major health problem responsible for 15% of all cancer diagnoses and 29% of all cancer deaths. The majority of respiratory system cancers are attributable to smoking tobacco[8].

The major types of respiratory system cancer are:

- Small cell lung cancer
- Non-small cell lung cancer
- Adenocarcinoma
- Large cell undifferentiated carcinoma
- Other lung cancers (carcinoid, Kaposi's sarcoma, melanoma)
- Lymphoma
- Head and neck cancer
- Mesothelioma, usually caused by exposure to asbestos dust.

IV. MODERN ANALYSIS & DIAGNOSIS TOOLS

The analysis and diagnosis tools for respiratory tract infection diseases can be broadly categorised as Respiratory Sound Analysis and Respiratory tract Imaging.

Respiratory sound Analysis:

Distinction between normal respiratory sounds and abnormal ones (such as crackles, wheezes…) is important for an accurate medical diagnosis. Respiratory sounds include invaluable information concerning the physiologies and pathologies of lungs and airways obstruction. Thus, the spectral density and amplitude of sounds can indicate the state of the lungs parenchyma, the dimension of the airways

and their pathological modification [9], [10]. Conventional methods make the use of stethoscope to hear the respiratory sound over the chest walls. However analysis from the sound heard on a stethoscope needs an experienced physician. Insufficient experience and improper auditory perception may lead to inaccurate or sometimes even false diagnosis. However digital recording of the sound signal and its computerized analysis may overcome these drawbacks. Research on Computer-based lung sound analysis started to appear in the literature in the early 1980s. The recent advancement in the field of signal processing is yet to be applied to determine the abnormality and disorder using computer-based lung sound auscultation [11][12].

Types of Respiratory Sounds

Respiratory signals can be classified into two major categories: normal lung sounds (NLS) and abnormal lung sounds (ALS) [13]. Most abnormal lung sounds are both

adventitious and nonstationary. While many types of abnormal lung sounds exist, the two major categories of abnormal lung sounds are wheezes and crackles [10].

A wheeze is a continuous adventitious sound that is characteristically "musical" in nature [14]. Wheezing is usually caused by airway obstruction in the lungs [13]. The presence of wheezes during breathing can indicate asthma, cyctic fibrosis, and bronchitis in a patient [13][14]. Wheezes are high-pitched in relation to normal breath sounds, and their frequency distribution is usually between the 400 Hz to 600 Hz range [13]. They typically last for longer than 100 ms [14]. Because wheezes have a defined frequency range, frequency domain analysis of a respiratory signal can reveal a wheeze.

A crackle is a discontinuous adventitious sound that is characterized by sharp bursts of energy [14]. Their duration is typically shorter than 20 ms, and they are characterized by a wide distribution of frequencies [14]. Because of this wide frequency distribution, it is difficult to pinpoint crackles in the

frequency domain. Crackles can be broken down into two additional categories. Fine crackles are high-pitched crackles that occur repeatedly over inspiration across multiple breathing cycles [13]. Coarse crackles are low-pitched sounds that appear early during inspiration or sometimes during expiration as a result of liquid filling small airways in the lungs [13]. The presence of crackles can indicate cardiorespiratory diseases, pneumonia, and chronic bronchitis [14].

The visualization methods are:

Phonopneumogram: it is a simultaneous and overlapped display of sound signal and airflow in time domain during breathing.

Spectrogram: it concerns representation in which time is represented in abscises, frequency in ordinate, and the intensity of the signal by a palette of colors.

Analysis Methods:

The various analysis methods are:

Fourier transforms: Applying a Fourier transform to an input signal yields a representation of the major frequency components of the signal. In respiratory signal analysis, the Fourier transform is particularly useful in revealing the presence of wheezes because wheezes occur in a known frequency band between 400 Hz and 600 Hz [14]

Wavelet Transform: Wavelet Transforms are able to detect sharp discontinuities in a signal, such as crackles. As an added benefit, Wavelet Transforms can also detect gradual, sinusoid-like characteristics of a signal, such as wheezes.

Gentic Algorithm: it is a search technique used to fi nd exact or approximate solutions to optimization and search problems. Genetic algorithms are categorized as global search heuristics. They are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover.

Neural Networks: are modeless systems that learn from the underlying relationships of data. They are organized in a way to simulate the cells of human brain.

Fuzzy Logic: Fuzzy Logic is a powerful problem-solving methodology with wide applications in industrial control and information processing. It provides a simple way to draw definite conclusions from vague, ambiguous or imprecise information. It resembles human decision making with its ability to work from approximate data and find precise solutions.

Respiratory Imaging Techniques:

Imaging involves investigations by chest X Rays, Computer tomography (CT) Scan, Bronchoscopy, Biopsy of the lung or pleura, Ventilation-Perfusion Scan, etc. A host of computer analysis techniques has been applied to CT images of the lung. Amongst the other imaging techniques the Computed Tomogrophic imaging is gaining importance. It is a medical imaging procedure that uses computer-processed X-rays to produce tomographic images_or 'slices' of specific areas of the body. These cross-sectional images are used for diagnostic and therapeutic purposes in various medical disciplines[15]. Digital geometry processing is used to generate a three-dimensional image of the inside of an object from a large series of two-dimensional X-ray images taken around a single axis of rotation[16].

V. OVERVIEW OF LITERATURE SEARCH

The study by Ali Keleş , and Aytürk Keleş [17]aims at diagnosing thyroid diseases with a expert system that we called as a ESTDD (expert system for thyroid disease diagnosis). They found fuzzy rules by using neuro fuzzy method, which will be emplaced in ESTDD system. ESTDD could diagnose with 95.33% accuracy thyroid diseases.

The work by E.I. Papageorgiou and etal. [18] focuses on the formalization of a Fuzzy Cognitive Map based decision support system using complementary the fuzzy decision tree method for producing fuzzy If-Then rules (extracted from data) accompanied with the available experts' knowledge.

In the paper by author Feyzullah Temurtas[19], a comparative chest diseases diagnosis was realized by using multilayer, probabilistic, learning vector quantization, and generalized regression neural networks. The chest diseases dataset were prepared by using patient's epicrisis reports from a chest diseases hospital's database.

The article by Erhan Elveren and Nejat Yumuşak [20], presents a study on tuberculosis diagnosis, carried out with the help of multilayer neural networks (MLNNs). For this purpose, an MLNN with two hidden layers and a genetic algorithm for training algorithm has been used.

In the paper by Orhan Er and Feyzullah Temurtas[21] , a study on Chronic Obstructive Pulmonary Disease (COPD) diagnosis was realized by using multilayer neural networks (MLNN). For this purpose, two different MLNN structures were used. One of the structures was the MLNN with one hidden layer and the other was the MLNN with two hidden layers.

Kumar C.Satish, Kanadaswamy A. Ramnatham [22], write Usefulness of the model parameters using artificial neural network with the model parameters as inputs and the condition of the subjects, normal or having any of the respiratory diseases, as outputs. Backpropagation algorithm incorporating Levenbury-Marquardt optimisation technique was used for training the neural network.

VI. THE NEURO- FUZZY APPROACH

From the vast literature survey the following advantages and limitations of Fuzy logic & Neural Network approach were noted.

Fuzzy logic advantages:

- Rapid computation due to intrinsic parallel processing nature
- Ability to deal with imprecise or imperfect information
- Resolving conflicts by collaboration, propagation and aggregation
- Improved knowledge representation and uncertainty reasoning
- Modelling of complex, non-linear problems
  Natural language processing/programming
  Capability.

Fuzzy logic limitations:

- highly abstract and heuristic
- need experts for rule discovery (data relationships)
- lack of self-organizing & self-tuning mechanisms of NN

Advantages of Neural Network:

- No need to know data relationships
- Self-learning capability
- Self-tuning capability

Applicable to model various systems

Limitations of NN:

- Unable to handle linguistic information
- Unable to manage imprecise or vague information
- Unable to resolve conflicts
- Unable to resolve conflicts
- Difficult to reach global minimum even by complex BP learning
- Rely on trial-and-errors to determine hidden layers and nodes

Neurofuzzy Techniques:

Neurofuzzy refers to the combination of fuzzy set theory and neural networks with the advantages of both:

- Handle any kind of information (numeric, linguistic, logical, etc.)
- Handle any kind of information (numeric, linguistic, logical, etc.)
- Resolve conflicts by collaboration and aggregation
- Self-learning, self-organizing and self-tuning capabilities
- No need of prior knowledge of relationships of data
- No need of prior knowledge of relationships of data
- Fast computation using fuzzy number operations

VII. CONCLUSION

Artificial Neural Network and Fuzzy Logic have been extensively used for diagnosis of different diseases of human body. In the field of artificial intelligence, neuro-fuzzy refers to combinations of artificial neural networks and fuzzy logic. Neuro- fizzy with all the advantages of Nueral networks and fuzzy logic can prove to be an effective tool for Analysis and Diagnosis of Respiratory Tract Infection Diseases.

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