CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD) PROGNOSTIC DIAGNOSIS UTILIZING FUZZY CLASSIFIER PROFICIENT APPROACH

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ABSTRACT

Chronic obstructive pulmonary disease (COPD) is a chronic, ongoing, progressive disease of the lower respiratory tract in the lungs. The hallmark of the disease is difficulty with breathing that slowly gets worse over time. COPD is usually caused by smoking, inhalation of irritant (pollutants, chemical fumes and dust) into the lungs, family history and aging. Symptoms of COPD are characterized by chronic coughing, shortness of breadth, wheezing, sputum, cyanosis, blue lip, blue skin, blue nail and insomnia. In this paper, the traditional procedure of the medical diagnosis of COPD employed by physicians is expressed using Fuzzy classifier. The proposed expert system eliminates uncertainty and imprecise associated with the diagnosis of COPD.

Keywords: COPD, diagnosis, fuzzy classifier, fuzzy logic, fuzzy set

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a chronic, ongoing, progressive disease of the lower respiratory tract in the lungs. COPD is an overreaching terms that refers to two other lung conditions chronic bronchitis and emphysema (HealthLine, 2011; MedicineNet, 2011; RightHealth, 2011; WrongDiagnosis, 2011). The hallmark of the disease is difficulty with breathing that slowly gets worse over time (HealthLine, 2011; MedicineNet, 2011 and WrongDiagnosis, 2011). COPD is a seriously disabling disease with the potential for major complications and is often eventually fatal. COPD is a major cause of disability and it's the fourth leading cause of death in the United State (NHLBI, 2011).

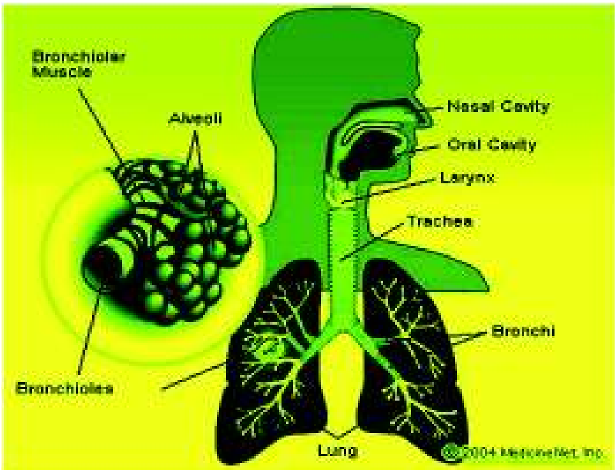


Fig. 1: *Pictorial Representation of how the lung work*

The lung is the organ for gas exchange; it transfers oxygen from the air into the blood and carbon dioxide (a waste product of the body) from the blood into the air. To accomplish gas exchange the lung has two components; airways and alveoli. The airways are branching, tubular passages like the branches of a tree that allow air to move in and out of the lungs. The wider segments of the airways are the trachea and the two bronchi (going to either the right or left lung). The smaller segments are called bronchioles. At the ends of the bronchioles are the alveoli, thin-walled sacs. The airways and alveoli can be conceptualized as bunches of grapes with the airways analogous to the stems and the alveoli analogous to the grapes. Small blood vessels (capillaries) run in the walls of the alveoli, and it is across the thin walls of the alveoli where gas exchange between air and blood takes places (MedicineNet, 2011).

Breathing involves inspiration followed by exhalation. During inspiration, muscles of the diaphragm and the rib cage contract and expand the size of the chest (as well as the airways and alveoli) causing negative pressure within the airways and alveoli. As a result, air is sucked through the airways and into the alveoli and the chest wall is enlarged. During exhalation, the same muscles relax and the chest wall springs back to its resting positions, shrinking the chest and creating positive pressure within the airways and alveoli. As a result, air is expelled from the lungs.

The walls of the bronchioles are weak and have a tendency to collapse, especially while exhaling. Normally, the bronchioles are kept open by the elasticity of the lung. Elasticity of the lung is supplied by elastic fibers which surround the airways and line the walls of the alveoli. When lung tissue is destroyed, as it is in patients with COPD who have emphysema, there is loss of elasticity and the bronchioles can collapse and obstruct the flow of air (MedicineNet, 2011). Normal lung tissues look a lot like a normal sponge. Emphysema often looks like an old sponge with large irregular holes and loss of the spring and elasticity (MedicineNet, 2011).

COPD develops most often as a result of smoking, but can also occur from long-term inhalation of irritants into the lungs, such as such as air pollution, chemical fumes, or dust. COPD develops when irritants are breathed into the respiratory tract into the bronchioles, small hollow passageways that branch off the main airway from the mouth and nose (Healthline, 2011). Normally, air and needed oxygen pass through the bronchioles and into the alveoli, tiny hollow sack-like structures in the lungs where oxygen is absorbed into the bloodstream. When air is mixed with smoke or irritants, it can damage the lungs and their ability to take in enough oxygen. Long-term inhalation of irritants results in a loss of elasticity in the bronchioles and alveoli, destruction of the walls between alveoli, and swelling and inflammation of the airways. There is also an abnormally large amount of mucus production, which can block airways. The longer the lungs are exposed to smoke or irritants, the more likely it is that you will develop COPD. It is also recommended to avoid long-term exposure to second hand smoke. The longer the lungs are exposed to smoke or irritants, the higher the risk for developing COPD. Family history and aging are other risk factors that may influence the development of COPD. The disease is usually diagnosed in middle-age or elderly people, but it can happen younger in life (HealthLine, 2011; WrongDiagnosis, 2011).

In healthy lungs, air and oxygen pass through the upper respiratory tract and into the bronchioles and the alveoli in the lungs. The alveoli are tiny hollow sack-like structures where oxygen is absorbed in to the bloodstream. However, long-term inhalation of smoke or other irritants results in a loss of elasticity in the bronchioles and alveoli, destruction of the walls between alveoli, and swelling and inflammation. There is also an abnormally large amount of mucus production, which can block airways.

The clinical symptoms of COPD include shortness of breath, a loose cough that produces large amount of mucus, and chest tightness. There is no cure for COPD (NHLBI, 2011). The damage done to the airways in the lungs by smoke or other irritants is permanent and is not reversible (HealthLine, 2011 and Wrong-Diagnosis, 2011). However, with regular medical care and consistent patient compliance with treatments and lifestyle changes, the symptoms of COPD can be minimized and progression of the disease can be slowed (WrongDiagnosis, 2011).

Making a diagnosis of COPD begins with taking a thorough medical history, including symptoms, smoking history and exposure to lung irritants. A physical examination is also performed and includes listening with a stethoscope to the sounds that lungs make during respiration. Lung sounds that may point to a diagnosis of COPD include wheezing and decreased lung sounds (Pauwels *et al.,* 2001).

Diagnostic testing can include lung function tests, such as a Spirometry (Bellamy *et al.,* 2005) which measures how much air is moved in and out of the lungs. A chest X-ray and CT scan of the chest can evaluate such factors as the presence of other conditions that may occur with or worsen COPD, such as pneumonia and congestive heart failure. An arterial blood gas tests a sample of blood taken from an artery for many parameters of effective breathing, including the oxygen level in the blood (Pauwels *et al.,* 2001).

Expert systems are knowledge-based systems that contain expert knowledge. An expert system is a program that can provide expertise for solving problems in a defined application area in the way the experts do. Fuzzy systems are rule-based expert systems based on fuzzy rules and fuzzy inference (PCAI, 2002; NIJ, 2011; Steffen, 2011).

Fuzzy sets were introduced by (Zadeh, 1965) to represent or manipulate data and information possessing non statistical uncertainties. Fuzzy sets provide a means of representing and manipulating data that are not precise, but rather fuzzy. Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth - truth values between "completely true" and "completely false" (Christos and Dimitros, 2008; Kasabov, 1998; Robert, 2000).

Fuzzy classification assumes the boundary between two neighboring classes as a continuous, overlapping area within which an object has partial membership in each class. It not only reflects the reality of many applications in which categories have fuzzy boundaries, but also provides a simple representation of the potentially complex partition of the feature space. (Sun and Jang, 1993) propose an adaptive-network-based fuzzy classifier to solve fuzzy classification problems. Conventional approaches of pattern classification involve clustering training samples and associating clusters to given categories. The complexity and limitations of previous mechanisms are largely due to the lacking of an effective way of defining the boundaries among clusters. This problem becomes more intractable when the number of features used for classification increases, (Christos and Dimitros, 2008; Kasabov, 1998; Robert 2000 and Rudolf, 2008).

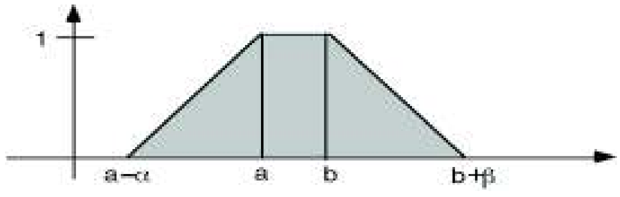
Fuzzy classifier is applied to the diagnosis of COPD using the model prescribed in Figure 2. The theory of fuzzy logic provides a mathematical strength to capture the uncertainties associated with human cognitive processes, such as thinking and reasoning. A fuzzy set A is called trapezoidal fuzzy number (Figure 2) with tolerance interval [a, b], left width α and right width β if its membership function has the following form
and we use the notation A = (a, b, α, β). It can easily be shown that

$$A(t) = \begin{cases} 1-(a-t)/\alpha & \text{if } a-\alpha \le t \le a \\ 1 & \text{if } a \le t \le b \\ 1-(t-b)/\beta & \text{if } a \le t \le b+\beta \\ 0 & \text{otherwise} \end{cases}$$

$[A]^{\gamma} = [a - (1 - \gamma)\,\alpha,\ b + (1 - \gamma)\,\beta]$, V γ ε [0, 1].
The support of A is (a − α, b + β).

Figure 2: *Trapezoidal fuzzy number*

Fuzzy systems often learn their rules from



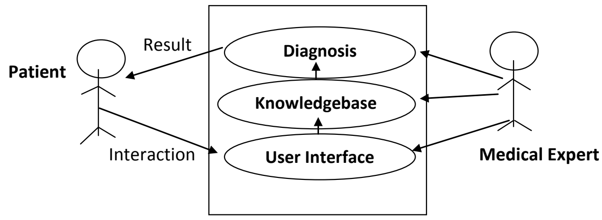
experts. When no expert gives the rules, adaptive fuzzy systems learns by observing how people regulate real systems (Leondes, 2010) The difference between classical and fuzzy logic is something called "the law of excluded middle" (Bart and Satoru, 1993; Ahmad, 2011). In standard set theory, an object does or does not belong to a set. There is no middle ground. In such bivalent systems, an object cannot belong to both its set and its compliment set or to neither of them. This principle preserves the structure of the logic and avoids the contradiction of object that both is and is not a thing at the same time (Zadeh, 1965). However, fuzzy logic is highly abstract and employs heuristic (experiment) requiring human experts to discover rules about data relationship (Angel and Rocio, 2011).

Fuzzy classification assumes the boundary between two neighboring classes as a continuous, overlapping area within which an object has partial membership in each class (Kuang *et al.,* 2011). It not only reflects the reality of many applications in which categories have fuzzy boundaries, but also provides a simple representation of the potentially complex partition of the feature space. In (Sun and Jang, 1993), propose an adaptive-network-based fuzzy classifier to solve fuzzy classification problems. Conventional approaches of pattern classification involve clustering training samples and associating clusters to given categories. The complexity and limitations of previous mechanisms are largely due to the lacking of an effective way of defining the boundaries among clusters. This problem becomes more intractable when the number of features used for classification increases, (Christos and Dimitros, 2008; Kasabov, 1998; Robert, 2000; Rudolf, 2008).

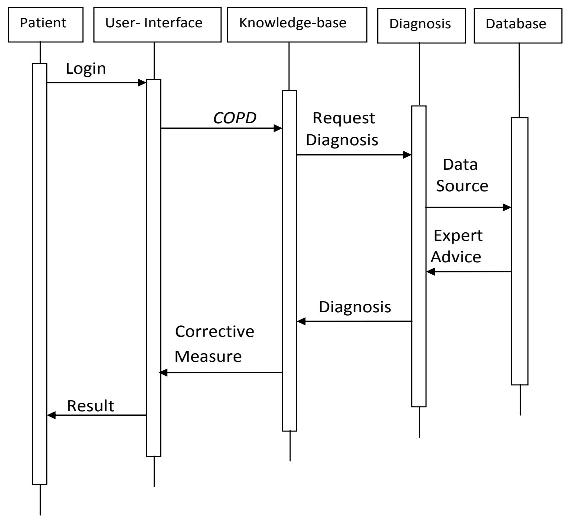
Fuzzy classifier is a subset of fuzzy system since there fully application is only utilized using fuzzy system. While the fuzzy system on one hand operate an object into class (enabling them to work together), fuzzy classifier provide the fuzzy self learning rule (conditional statement) which enable the system to be fully optimal. Fuzzy systems are fundamental methodologies to represent and process linguistic information, with mechanisms to deal with uncertainty and imprecision (Reza and Ali, 2011).

METHODOLOGY

The system is developed in an environment characterized by Microsoft Windows XP Professional Operating System, Microsoft Access Database Management system, Visual Basic Application Language, Microsoft Excel and UML: Unified modeling Language (Use-case and Sequence diagram); which was used to capture and model some of the functionalities in the system. UML is an excellent tool for modeling objects and the relationship between objects and classes (Djam and Kimbi, 2011). The UML approach helps to depict the system in many different views thus giving a quick structural representation of the system. In this paper the use-case and sequence diagram where explored.



The use-case diagram is the description of the system behavior from the user's point of view. It is a valuable tool due system analysis and design as developing use-case help to understand system requirement. The use-case diagram is shown in Figure 3.



The sequence diagram a derivative of the use-case analysis illustrates the processing described in the use-case scenarios. The sequence diagram describes how the objects in the system interact over time. The objects identified in the system are patient, the user interface, knowledge-base, diagnosis and database. The objects interact in the sequence shown in Figure 4 by passing messages across the timelines represented by arrows.

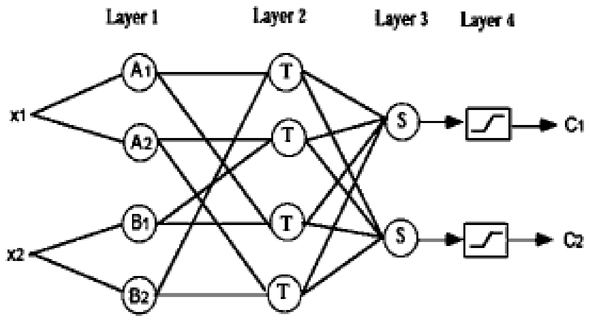


Figure 5: *Fuzzy Classifier System for the diagnosis of Chronic Obstructive Pulmonary Disease*

The system parades two input variables X_1 and X_2 which are symptoms of COPD, clearly shown in Figure 5. The training data are categorized by two classes C_1 and C_2. Each input is represented by the two linguistic terms, thus we have four rules.

Layer 1**:** The output of the node is the degree to which the given input satisfies the linguistic label associated to this node. This is governed by the bell-shaped membership functions

$$A_i(u) = \exp[-1/2 (u - a_{i1}/b_{i1})^2],$$

$$B_i(v) = \exp[-1/2 (v - a_{i2}/b_{i2})^2],$$

which represent the linguistic terms, where $\{a_{i1}, a_{i2}, b_{i1}, b_{i2}\}$ is the parameter set. As the values of these parameters change, the bell-shaped functions vary accordingly, thus exhibiting various forms of membership functions on linguistic labels A_i and B_i. In fact, any continuous, such as trapezoidal and triangular-shaped membership functions are also quantified candidates for node functions in this layer. The initial values of the parameters are set in such a way that the membership functions along each axis satisfy:- completeness, normality and convexity. The parameters are then tuned with a descent-type method.

Layer 2**:** Each node generates the signal corresponding to the conjunctive combination of individual degrees of match of COPD symptoms. The output signal is the firing strength of the fuzzy rule with respect to COPD.

We take the linear combination of the firing strengths of the rules at Layer 3 and apply sigmoidal function at Layer 4 to calculate the degree of belonging to a certain class. Given training set $\{(x^k, y^k), k = 1 . . . K\}$ where x^k refers to the k^{th} input pattern then

$$Y^K = \begin{cases} (1, 0)^T \text{ If } X^K \text{ belongs to Class 1} \\ (0, 1)^T \text{ If } X^K \text{ belongs to Class 2} \end{cases}$$

The error function for pattern k can be defined by $\mathbf{E_K = 1/2\ [(0_1^K - Y_1^K)^2 + (0_2^K - Y_2^K)^2]}$

where y^k is the desired output and o^k is the computed output.

Using fuzzy IF-THEN rules to describe a classifier**,** assume that K patterns $x_p = (x_{p1}, x_{pn})$, p = 1. . . K is given from two classes, where x_p is an n-dimensional crisp vector. Typical fuzzy classification rules for n = 2 are like

IF x_{p1} is small and x_{p2} is very large THEN $x_p = (x_{p1}, x_{p2})$ belongs to Class C_1

IF x_{p1} is large and x_{p2} is very small THEN $x_p = (x_{p1}, x_{p2})$ belongs to Class C_2

where x_{p1} and x_{p2} are the features of pattern (or object) p, small and very large are linguistic terms characterized by appropriate membership functions.

The task of fuzzy classification of COPD is to generate an appropriate fuzzy partition of the feature space. In this context the word appropriate means that the number of misclassified patterns is very small or zero. Then the rule base should be optimized by deleting rules which are not used. The scheme is extensible to any number of input and classes.

RESULTS AND DISCUSSION

The fuzzy partition for each input feature consists of the clinical symptoms of COPD (chronic coughing, shortness of breath, wheezing, sputum, cyanosis, blue lips, blue skin, blue nails, insomnia, irritability and headache). However, it can occur that if the fuzzy partition of COPD is not set up correctly, or if the number of linguistic terms for the input features is not large enough, then some patterns will be misclassified. The rules that can be generated from the initial fuzzy partitions of the classification of COPD is thus

a. Experiencing COPD (C1)

b. Might be experiencing COPD (C2)

c. Not experiencing COPD (C3)

If the patients is experiencing five or more clinical symptoms (C1), experiencing four clinical symptoms (C2) and if the patients is experiencing less than four clinical symptoms (C3).

The Fuzzy IF-THEN Rules (R_i) for COPD is

R1: IF the patience is experiencing chronic coughing THEN he/she has class C3.

R2: IF the patience is experiencing chronic coughing and shortness of breath THEN he/she has class C3.

R3: IF the patience is experiencing chronic coughing, shortness of breath and wheezing THEN he/she has class C3.

R4: IF the patience is experiencing chronic coughing, shortness of breath, wheezing and sputum THEN he/she has class C2.

R5: IF the patience is experiencing chronic coughing, shortness of breath, wheezing, sputum and cyanosis THEN he/she has class C1.

R6: IF the patience is experiencing chronic coughing, shortness of breath, wheezing, sputum, cyanosis and blue lip THEN he/she has class C1.

R7: IF the patient is experiencing chronic coughing, shortness of breath, wheezing, sputum, cyanosis, blue lip and blue skin THEN he/she has class C1.

R8: IF the patient is experiencing chronic coughing, shortness of breath, wheezing, sputum, cyanosis, blue lip, blue skin and blue nail THEN he/she has class C1.

R9: IF the patient is experiencing chronic coughing, shortness of breath, wheezing, sputum, cyanosis, blue lip, blue skin, blue nail and insomnia THEN he/she has class C1.

R10: IF the patient is experiencing chronic coughing, shortness of breath, wheezing, sputum, cyanosis, blue lip, blue skin, blue nail, insomnia and irritability THEN he/she has C1.

R11: IF the patient is experiencing chronic coughing, shortness of breath, wheezing, sputum, cyanosis, blue lip, blue skin, blue nail, insomnia, irritability and headache THEN he/she has C1.

Table 1: *Degree of membership of COPD symptoms; Scale (0.00 -1.00)*

SYMPTOMS OF COPD (FUZZY SET OR PARAMETERS)	CODES	DEGREE OF MEMBERSHIP OF COPD		
		CLUSTER 1 (C_1)	CLUSTER 2 (C_2)	CLUSTER 3 (C_3)
Chronic coughing	P01	0.50	0.40	0.10
Shortness of breadth	P02	0.50	0.10	0.40
Wheezing	P03	0.40	0.55	0.05
Sputum	P04	0.10	0.60	0.30
Cyanosis	P05	0.62	0.28	0.10
Blue lip	P06	0.05	0.80	0.15
Blue skin	P07	0.10	0.13	0.77
Blue nail	P08	0.80	0.10	0.10
Insomnia	P09	0.20	0.69	0.11
Irritability	P10	0.51	0.39	0.10
Headache	P11	0.66	0.10	0.24
RESULTS		Experiencing COPD	Might be experiencing COPD	Not experiencing COPD

The COPD **prognosis** is very severe if any patient is diagnosed with cluster 1 (C1), therefore the patient should consult a physician immediately or could experience untimely death.

The degree of membership of COPD symptoms order in the following classes for a typical scenario is presented in Table 1. From Cluster 1, represent possible situation of *"experiencing COPD"* because at least five of the symptoms are pronounced. In cluster 2, there *"might be experiencing COPD"* since only four of the symptoms are pronounced. Cluster 3 *"Not be COPD"* but possibly some other disease since only one of the symptom of COPD is pronounced.

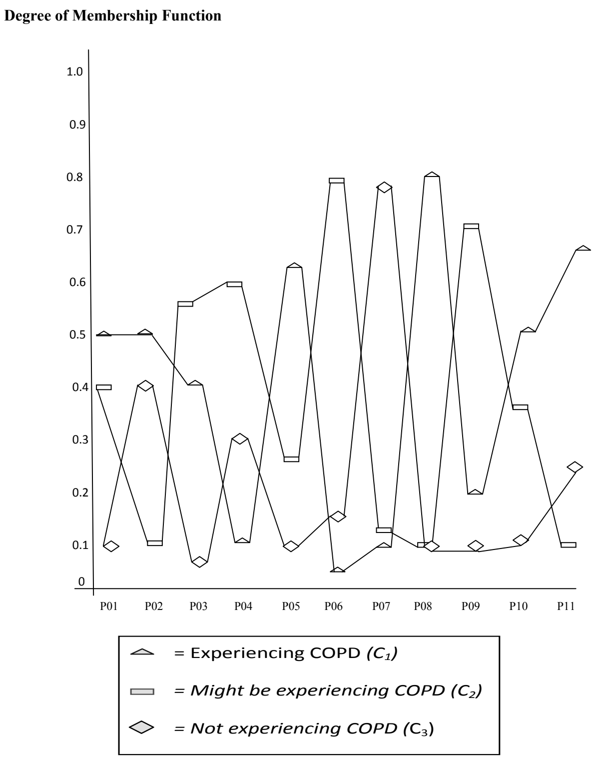


Figure 6: *Graphical representation of Membership Grades of COPD clinical symptoms*

The graphical representation in **Figure 6,** is a representation of Table 1 and clearly show six clinical symptoms with high degree of "Experiencing COPD" in Cluster 1, four clinical symptoms with high degree of "Might be experiencing COPD" in Cluster 2 and a symptom with high degree of "Not experiencing COPD" in Cluster 3.

CONCLUSION

This work demonstrates the application of Information and Communication Technology (ICT) in the domain of differential diagnosis of COPD using fuzzy classifier method when given a set of symptoms. Using fuzzy classifier methodology, differential diagnosis of COPD into three major classes "Experiencing COPD, Might be experiencing COPD and not experiencing COPD" was presented. The system is designed to diagnose COPD and not to prescribe drugs but can be expanded to do so after some more research have been carried out. Soon there would be a fully computerized system to handle diagnosis of diseases in general. A system of this nature that has the ability to diagnose a person suffering from COPD should be introduced in the health sector to assist doctors in making diagnosis most especially in cases of severe illnesses.

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