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Fuzzy Cluster Means Expert System for the Diagnosis of Tuberculosis

By Imianvan A.A. , Obi J.C.
University of Benin

Abstract- : -Tuberculosis (TB) is a global public health problem of enormous dimension. Tuberculosis is usually associated with mycobacterium tuberculosis (the bacterium causing tuberculosis). TB is an infectious disease, transmitted and spread via aerosols (droplets from the mouth and respiratory tract) that are coughed, sneezed, or forcibly expelled from the body to the surrounding air. These droplets, when inhaled by a susceptible host, can infect a new person and, within weeks to months, the disease begins to develop within the infected person. The lungs are the primary site of infection. The disease can spread to almost any other organ such as: kidneys, bladder, bones, spine, liver, spleen and brain. TB symptoms are characterized by low grade fever, coughing, fatigue, and a loss of appetite. Later, hemoptysis (coughing up blood), may occur. The application of Fuzzy Cluster Means (FCM or Fuzzy C-Mean) analysis to the identification of different types of tuberculosis is the focal point of this paper. Application of cluster analysis involves a sequence of methodological and analytical decision steps that enhances the quality and meaning of the clusters produced. The uncertainties often associated with analysis of tuberculosis test data are eliminated by the proposed system.

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FUZZY CLUSTER MEANS EXPERT SYSTEM FOR THE DIAGNOSIS OF TUBERCULOSIS

Strictly as per the compliance and regulations of:

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Abstract-Tuberculosis (TB) is a global public health problem of enormous dimension. Tuberculosis is usually associated with mycobacterium tuberculosis (the bacterium causing tuberculosis). TB is an infectious disease, transmitted and spread via aerosols (droplets from the mouth and respiratory tract) that are coughed, sneezed, or forcibly expelled from the body to the surrounding air. These droplets, when inhaled by a susceptible host, can infect a new person and, within weeks to months, the disease begins to develop within the infected person. The lungs are the primary site of infection. The disease can spread to almost any other organ such as: kidneys, bladder, bones, spine, liver, spleen and brain. TB symptoms are characterized by low grade fever, coughing, fatigue, and a loss of appetite. Later, hemoptysis (coughing up blood), may occur. The application of Fuzzy Cluster Means (FCM or Fuzzy C-Mean) analysis to the identification of different types of tuberculosis is the focal point of this paper. Application of cluster analysis involves a sequence of methodological and analytical decision steps that enhances the quality and meaning of the clusters produced. The uncertainties often associated with analysis of tuberculosis test data are eliminated by the proposed system.

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I. Introduction

Tuberculosis (TB) is a global health problem. It is estimated that about one billion individuals are infected world wide with tuberculosis, with 10 million new cases and over 3 million deaths per year (Taura et al., 2008). Tuberculosis is amongst the world's leading cause of death from a single infectious disease.

TB most commonly affects the lungs but also can involve any organ of the body. Tuberculosis has been known under a variety of names during the course of history. It has been a difficult disease to diagnose and has been confused with many other diseases. The actual name "Tuberculosis" was introduced during the first half of the nineteenth century. It refers to the diseased condition caused by infectious agents known as mycobacterium tuberculosis or tubercle bacilli (Neil and Janet, 2005). The disease has also been known under other names, such as phthisis, Scrofula, tabes, bronchitis, and inflammation of the lungs, hectic fever, gastric fever, and lupus (Neil and Janet, 2005). It was also known as the great white plague or "consumption" (MedicineNet, 2005).

About - Department of Computer Science, University of Benin, Benin City. Nigeria.
E-mail: tonyvanni@yahoo.com

It's a rod-shaped bacterium 2 to 4 micrometers in length (CWS, 2000). Although tuberculosis can attack the whole body it is frequently known more for its damage to the lungs (Neil and Janet, 2005). TB was first isolated in 1882 by a German physician named Robert Koch who received the Nobel Prize for this discovery. TB is usually transmitted and spread via aerosols (droplets from the mouth and respiratory tract) that are coughed, sneezed, or forcibly expelled from the body to the surrounding air. These droplets, when inhaled by a susceptible host, can infect a new person and, within weeks to months, the disease begins to develop in that infected person. Apart from the lungs, the disease can spread to almost any other organ such as: kidneys, bladder, bones, spine, liver, spleen and brain. TB infections are characterized by low grade fever, coughing, fatigue, and a loss of appetite. Later, coughing with hemoptysis (blood in the sputum), may occur. If the infection in the lung worsens, then further symptoms can include chest pain, and shortness of breath. If the infection spreads beyond the lungs, the symptoms will depend upon the organs involved (MedicineNet, 2011).

Fuzzy logic provides a means for representing and manipulating data that are not precise, but rather fuzzy. Fuzzy logic presents an inference morphology that enables appropriate human reasoning capabilities to be applied to knowledge-based systems. The theory of fuzzy logic encompasses a mathematical strength to capture the uncertainties associated with human cognitive processes. This paper presents a Fuzzy Cluster Mean (Fuzzy C-Mean or FCM) knowledge-based model for the diagnosis of TB. Fuzzy C-means clustering algorithm is being used as the problem solving and reasoning algorithm in the inference engine of the knowledge base system for the evaluation, classification and matching of patterns to more than one class of tuberculosis. Statistics, Neural network and Physiology are also incorporated. The main objective is to classify and match any individual independently with more than one cluster depending on the degree of membership.

II. Literature Review

There are many form of TB, but for the purpose of this paper we shall consider seven of them (Taura et al., 2008). These are

i. Tuberculosis Gastrointestinal

ii. Tuberculosis Meningitis
iii. Tuberculosis Lymphadenitis (Scrofula)
iv. Cutaneous Tuberculosis (Lupus vulgaris; Tuberculosis verrucosa; Milary
v. tuberculosis)
vi. Osteo-articular Tuberculosis
vii. Genitourinary Tuberculosis
viii. Drug-resistant Tuberculosis (Multi-drug resistant tuberculosis (MDR-TB) and
ix. Extensively drug-resistant tuberculosis (XDR-TB))

III. Tuberculosis Meningitis

Tuberculosis meningitis is a TB infection of the brain and the spinal cord. The initial symptoms can be irritability and restlessness. Later the patient may develop other symptoms such as a stiff neck, headaches, vomiting, and variations in mental behavior, seizures, or coma.

IV. Gastrointestinal Tuberculosis

Gastrointestinal tuberculosis is TB of the gastrointestinal tract: mouth, oesophagus, stomach, small and large intestine, and the anus. The symptoms are abdominal pain, fever, weight loss, nausea, vomiting, and change in bowel habits.

V. Tuberculosis Lymphadenitis (Scrofula)

Tuberculosis lymphadenitis is TB of the lymph nodes, usually along the neck. The symptoms are the formation of masses along the neck, and if the disease is advanced the mass may burst and form a draining sinus.

VI. Cutaneous Tuberculosis

Cutaneous tuberculosis is TB of the skin or mucous membrane from an external source of mycobacteria. There are several types of cutaneous tuberculosis: Lupus vulgaris, tuberculosis verrucosa cutis and milary tuberculosis.

• Lupus vulgaris is a persistent type of cutaneous TB. The symptoms are small reddish brown lesions that are found on the face, eyelids, around the nose, cheeks, and ears.

• Tuberculosis verrucosa cutis is only contracted through direct skin inoculation when an individual had been previously exposed to mycobacteria. This type of cutaneous TB can last for years. The symptoms are reddish brown wart-like growths on the body, skin lesions on hands, feet, buttocks, elbows and knees. Sometimes pus will seep through the fissures present in the lesions

• Milary tuberculosis is a cutaneous TB that starts off as a pulmonary TB infection which then travels through the bloodstream. The symptoms are small red spots on the skin (which are sometimes concentrated to the trunk of the body), necrosis of infected areas, and the development of ulcers or abscesses on the skin.

VII. Osteo-Articular Tuberculosis

Osteo-articular tuberculosis is TB of the joints: knees, hips, ankles, wrists, shoulders, and elbows. It usually affects one joint. The symptoms are similar to those experienced by individuals with arthritis and pain or stiffness is only felt in the infected area.

VIII. Genitourinary Tuberculosis

Genitourinary tuberculosis is TB that initially begins as a pulmonary (lungs) TB infection which then travels through the bloodstream to the genitourinary tract. The genitourinary tract includes the urinary tract and the reproductive system. The symptoms are blood present in urine, painful or uncomfortable urination, and experiencing pain on one side of the body between the upper abdomen and back.

IX. Drug-Resistant Tuberculosis

Drug-resistant tuberculosis is a TB infection that does not respond to drugs used for treatment of TB infection. This type of TB occurs due to the poor management of TB care or the individual was infected by bacteria that were already drug-resistant. There are two types of drug-resistant tuberculosis: multiple drug-resistant tuberculosis and extensive drug-resistant tuberculosis.

• Multi-drug resistant tuberculosis (MDR-TB) is resistant to no less than two of the first-line of drugs used to fight TB infection.

• Extensively drug-resistant tuberculosis (XDR-TB) is resistant to three or more of the second-line of drugs used to fight TB infection. This makes it the worst kind of TB infection as treatment for the TB infection is drastically reduced.

The symptoms for MDR-TB and XDR-TB are similar to the symptoms experienced by individuals suffering with pulmonary TB. These symptoms are weight loss, fever, night sweats, coughing and/or coughing up blood, fatigue, and chest pain.

Fuzzy Logic (FL) is a branch of machine intelligence that helps computers paint pictures of uncertain world. Fuzzy sets were introduced by Zadeh (1965) as a means of representing and manipulating data that are not precise, but rather fuzzy. Fuzzy logic provides an inference morphology that enables appropriate human reasoning capabilities to be applied to knowledge-based systems. 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 1) with tolerance interval [a, b], left width α and right width β if its membership function has the following form

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

and we use the notation A = (a, b,α,β). It can easily be shown that

$[A]^{\gamma} = [a - (1 - \gamma)\,\alpha,\ b + (1 - \gamma)\,\beta],\ \forall \gamma\ \varepsilon\ [0, 1].$

The support of A is (a − α, b + β).

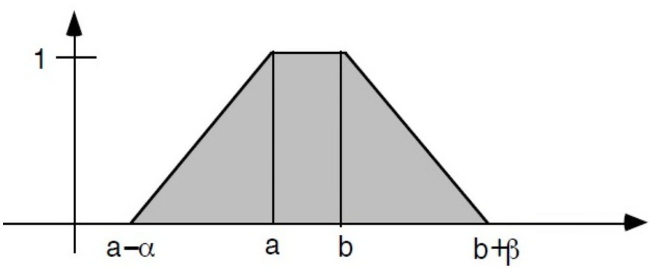

Figure 1: *Trapezoidal fuzzy number.*

X. Fuzzy Clustering

Clustering involves the task of dividing data points into homogeneous classes or clusters so that items in the same class are as similar as possible and items in different classes are as dissimilar as possible (Yang and Wang 2001). Clustering can also be thought of as a form of data compression, where a large number of samples are converted into a small number of representative prototypes or clusters (Giles and Draeseke 2001). Depending on the data and the application, different types of similarity measures may be used to identify classes, where the similarity measure controls how the clusters are formed (Inyang 2005). Some examples of values that can be used as similarity measures include distance, connectivity, and intensity (Berks et al 2000).

In non-fuzzy or hard clustering, data is divided into crisp clusters, where each data point belongs to exactly one cluster (Albayrak and Amasyali 2003). In fuzzy clustering, the data points can belong to more than one cluster, and associated with each of the points are membership grades which indicate the degree to which the data points belong to the different clusters (Nascimento, 1991).

XI. Overview of Fuzzy Clustering Means (FCM) Algorithm

The FCM algorithm is one of the most widely used fuzzy clustering algorithms. The FCM algorithm attempts to partition a finite collection of elements $X=\{X_1, X_2,...,X_n\}$ into a collection of c fuzzy clusters with respect to some given criterion. Given a finite set of data, the algorithm returns a list of c cluster centers V, such that

$V = V_i$, i=1, 2,..., c

and a partition matrix U such that

$U = U_{ij}$, i =1,..., c , j =1,..., n

where U_{ij} is a numerical value in [0, 1] that tells the degree to which the element X_j belongs to the i-th cluster.

The following is a linguistic description of the FCM algorithm, which is implemented by fuzzy Logic. The algorithm is as follows;

Step 1: Select the number of clusters c ($2 \le c \le n$), exponential weight μ ($1 < \mu < \infty$), initial partition matrix U^0, and the termination criterion **ε**. Also, set the iteration index 1 to 0.

Step 2: Calculate the fuzzy cluster centers $\{V_i^1 \mid i=1, 2,..., c\}$ by using U^1.

Step 3: Calculate the new partition matrix U^{1+1} by using $\{V_i^1 \mid i=1, 2,..., c\}$.

Step 4: Calculate the new partition matrix = $|| U^{1+1} - U^1 || = | U_{ij}^{1+1} - U_{ij}^1 |$. If >ε, then set l = l + 1 and go to **step 2**. If ≤ε, then stop.

The initial cluster centers are computed in two ways; Arithmetic Means of all the data points or running FCM several times each starting with different initial cluster centers. In this work the first method is adopted.

XII. Methodology

This expert system which employ fuzzy C-Means for the diagnosis of TB is developed in an environment characterized by Microsoft Window XP professional Operating System, Microsoft Access Database Management system, Visual Basic Application Language and Microsoft Excel.

Neuro Solutions and Crystal reports were used for neural network analysis and graphical representation. An approach for analyzing clusters to identify meaningful pattern for determining whether a patient suffers from TB or not is presented. The system provides a guide for diagnosis of TB within the decision-making framework.

The process for the medical diagnosis of TB starts when an individual consults a physician (doctor) and presents a set of complaints (symptoms). The physician then requests further information from the patient or from others close to him who knows about the patient's symptoms in severe cases. Data collected include patient's previous state of health, living condition and other medical conditions. A physical examination of the patient condition is conducted and in most cases, a medical observation along with medical test(s) is carried out on the patient prior to medical treatment.

From the symptoms presented by the patient, the physician narrows down the possibilities of the illness that corresponds to the apparent symptoms and make a list of the conditions that could account for what is wrong with the patient. These are usually ranked in possibility order (Low, Moderate and high). The physician then conducts a physical examination of the patient, studies his or her medical records and ask further questions, as he goes in an effort to rule out as many of the potential conditions as possible. When the list has been narrowed down to a single condition, it is called differential diagnosis and provides the basis for a hypothesis of what is ailing the patient. Until the physician is certain of the condition present; further medical test are performed or schedule such as medical imaging, scan, X-rays in part to conform or disprove the diagnosis or to update the patient medical history. Other Physicians, specialist and expert in the field may be consulted (sought) for further advices.

Despite all these complexities, most patient consultations are relatively brief because many diseases are obvious or the physician's experience may enable him to recognize the condition quickly. Upon the completion of the diagnosis by the physician, a treatment plan is proposed, which includes therapy and follow-up (further meeting and test to monitor the ailment and progress of the treatment if needed). Review of diagnosis may be conducted again if there is failure of the patient to respond to treatment that would normally work. The procedure of diagnosing a patient suffering from TB is synonymous to the general approach to medical diagnosis. The physician may carry out a precise diagnosis, which requires a complete physical evaluation to determine whether the patient have TB. The examining physician accounts for possibilities of having TB through an interview, physical examination and laboratory test. Many primary health care physicians use screening tools for TB evaluation.

A thorough diagnostic evaluation may include a complete history of the following:

a. When did the symptoms start?

b. How long have the symptoms lasted?

c. How severe are the symptoms?

d. Have the symptoms occurred before, and if so, were they treated and what treatment was received?

XIII. Results and Discussion

To design the FCM Knowledge Base System for diagnosis of TB, we design a system which consists of a set of parameters needed for diagnosis (here, we are using 20 basic and major parameters) presented in Table 1.

1.	Coma (Seizure)
2.	Stiff Neck
3.	Headache
4.	Abdominal Pain
5.	Weight Pain
6.	Fever
7.	Masses along the neck
8.	Draining Sinus
9.	Small Reddish brown lesions(face, eyelid, nose, cheek and ear
10.	Reddish brown wart-like growth on the body
11.	Skin lesions on hand, feet, elbow and knees.
12.	Ulcer or abscesses on the Skin
13.	Necrosis of infected Skin
14.	Stiffness of affected area
15.	Blood present in Urine
16.	Painful or uncomfortable Urination
17.	Hemopysis (coughing up blood)
18.	Fatigue
19.	Chest pain
20.	Night Sweat

Table: 1 Symptoms of Tuberculosis (TB)

Figure 1 presents the model of the FCM system for the diagnosis of TB. It comprises of knowledge base system, fuzzy c-means inference engine and decision support system. The knowledge base consists of the database Engine. The knowledge base system holds the symptoms for TB.

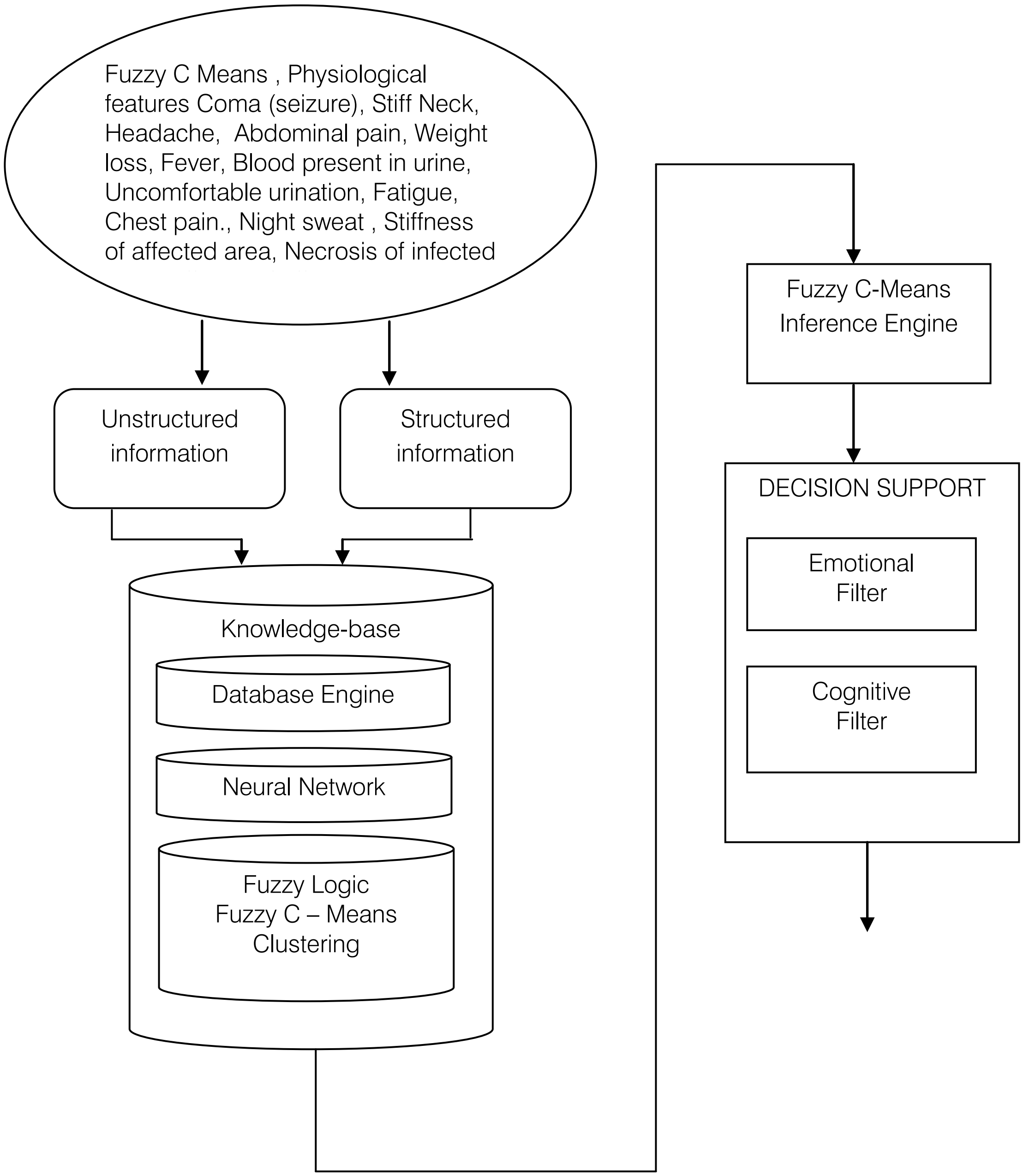

Figure 1: Architecture of FCM Knowledge Base System for the diagnosis of TB

The values for the diagnosis of TB symptoms are not precise hence the adoption of fuzzy logic as a means of analyzing these information. The different forms of TB symptoms, therefore, constitute the fuzzy parameters of the knowledge base system. The fuzzy set of parameters is represented by 'P', which is defined as $P = \{P_1, P_2 \ldots, P_n\}$

where P_i represents the j^{th} parameter and n is the number of parameters (in this case n=20). Neural network provides the structure intelligent learning for all forms of TB symptoms, which serves as a platform for the inference engine. The inference engine consists of reasoning algorithms, driven by production rules. These production rules are evaluated by using the forward chaining approach of reasoning. The fuzzy logic and fuzzy C-means algorithm provides the rules for the partitioning of patients into a number of homogenous clusters with respect to a suitable similarity measure.

In this paper, the patients were classified into seven form of TB according to physician. TB meningitis refer to patients experiencing four or less of the enlisted symptoms along the brain and the spinal cord, Gastrointestinal tuberculosis refers to patients who have 5 or more of the enlisted symptoms along the

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gastrointestinal tract (mouth, oesophagus, stomach, small and large intestine, and the anus), **TB lymphadenitis** refers to patients experiencing four or less of the under listed symptoms along the lymph nodes, (usually along the neck), **Cutaneous TB** refers to patients experiencing four or less of the under listed symptoms along the skin or mucous membrane, **Osteo-articular TB** refers to patients experiencing four or less of the under listed symptoms along the joints: knees, hips, ankles, wrists, shoulders, and elbows (It usually affects one joint). **TB genitourinary** refers to patients experiencing four or less of the under listed symptoms along the genitourinary tract includes the urinary tract and the reproductive system and **Drug-resistant TB** refers to patients experiencing four or less of the under listed symptoms after drugs has been prescribed to fight the disease.

Each of the symptoms highlighted in Table 1 is represented with P (starting from 1 – 20 i.e. P_1 – P_{20}). In addition, we form seven clusters namely, TB meningitis, gastrointestinal TB, TB lymphadenitis Cutaneous TB, Osteo-articular TB, TB genitourinary and Drug-resistant TB. These will make up the degree of Membership or intensity.

Table 2 below represents the degree of membership, for instance, P10 in cluster 1, we notice it has 0.51. In term of percentage it can be represented as 51%, in cluster 2, 9%, in cluster 3, 10%, in cluster 4, 5%, in cluster 5, 10%, in cluster 6, 5% and in cluster 7, 10%. This means that the degree of symptoms of P10 matches **51% of TB meningitis, 9% of Gastrointestinal TB**, **10% of TB lymphadenitis, 5% 0f Cutaneous TB, 10 % of Osteo-articular TB, 5% of TB genitourinary and 10 of Drug-resistant TB**.

The FCM clustering distribution shown Figure 2 depicts a total of two symptoms with high degree of membership of **TB meningitis,** eight symptoms with high degree of membership of **Gastrointestinal TB**, two symptoms with high degree of membership of **TB lymphadenitis,** two symptoms with high degree of membership of **Cutaneous TB,** two symptoms with high degree of membership of **Osteo-articular TB**, two symptoms with high degree of membership of **TB genitourinary** and two symptoms with high degree of membership of **Drug-resistant TB.**

Table 2: FCM membership grade of all patients in all clusters

CODES	DEGREE OF MEMBERSHIP						
	CLUSTER 1	CLUSTER 2	CLUSTER 3	CLUSTER 4	CLUSTER 5	CLUSTER 6	CLUSTER 7
P01	0.05	0.50	0.10	0.10	0.10	0.05	0.10
P02	0.50	0.05	0.10	0.05	0.05	0.15	0.10
P03	0.10	0.55	0.05	0.15	0.05	0.05	0.05
P04	0.15	0.10	0.10	0.05	0.05	0.05	0.50
P05	0.10	0.10	0.10	0.05	0.05	0.58	0.02
P06	0.05	0.05	0.05	0.05	0.53	0.17	0.10
P07	0.08	0.06	0.04	0.62	0.05	0.09	0.06
P08	0.08	0.10	0.56	0.10	0.02	0.10	0.04
P09	0.05	0.66	0.11	0.06	0.05	0.04	0.03
P10	0.51	0.09	0.10	0.05	0.10	0.05	0.10
P11	0.05	0.61	0.10	0.04	0.05	0.10	0.05
P12	0.10	0.20	0.50	0.05	0.0 7	0.04	0.04
P13	0.04	0.15	0.05	0.56	0.05	0.05	0.10
P14	0.08	0.05	0.05	0.03	0.72	0.03	0.04
P15	0.05	0.11	0.06	0.08	0.06	0.55	0.09
P16	0.06	0.04	0.16	0.12	0.04	0.04	0.54
P17	0.05	0.56	0.14	0.05	0.05	0.08	0.07
P18	0.05	0.65	0.10	0.05	0.05	0.05	0.05
P19	0.10	0.59	0.01	0.05	0.05	0.10	0.10
P20	0.09	0.51	0.10	0.05	0.10	0.05	0.10

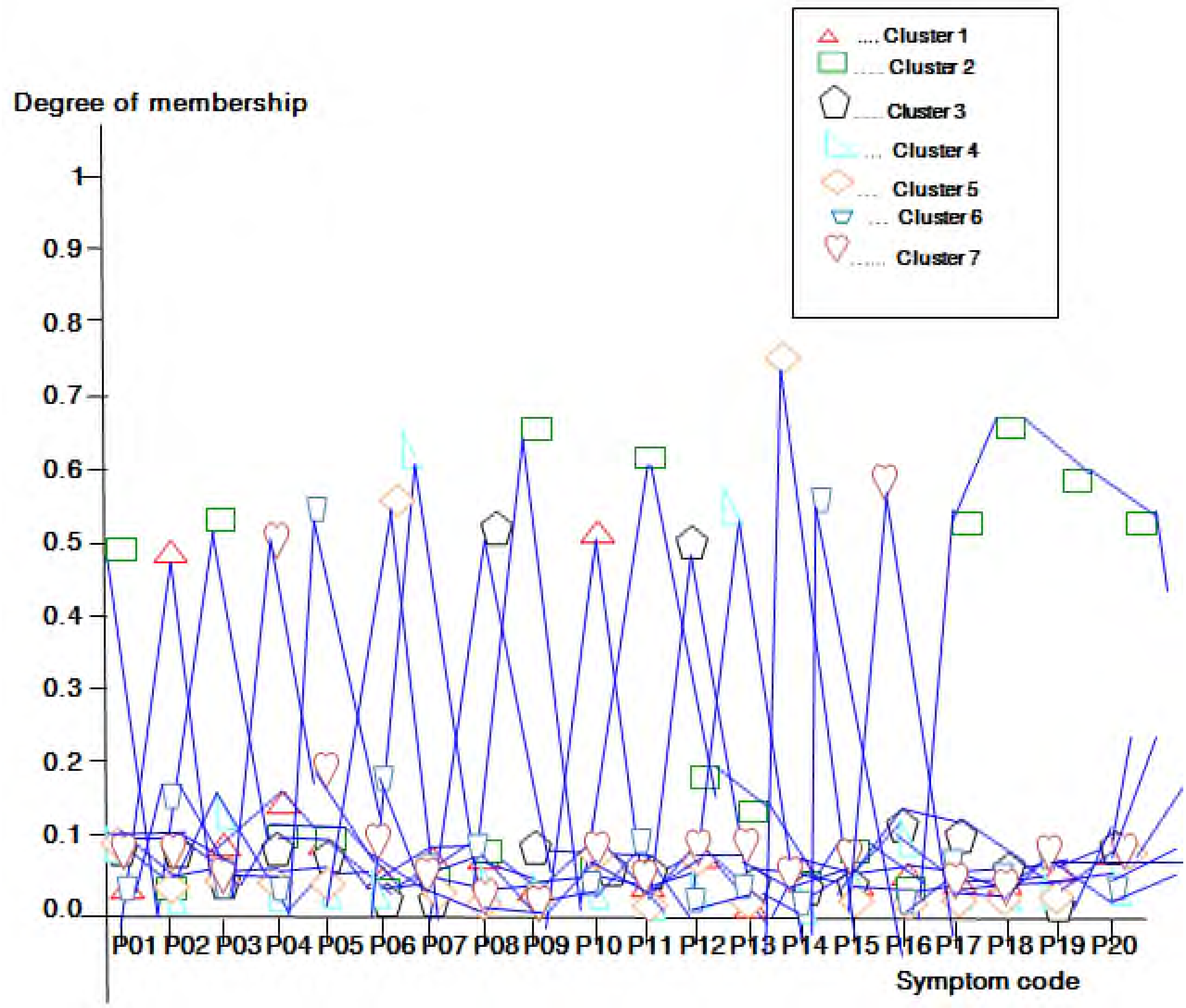

Figure 2: Graphical representation of Membership Grades of TB symptoms.

XIV. Conclusion

The need to design a system that would assist doctors in medical diagnosis has become imperative and hence cannot be over emphasized. This paper present a diagnostic fuzzy cluster means system to help in diagnosis of Tuberculosis using a set of symptoms. This advanced system which uses a set of clustered data set is more precise than the traditional system. The classification, verification and matching of symptoms to the seven groups of clusters was necessary especially in some complex scenarios. This paper demonstrates the practical application of IT (Information Technology) in the domain of diagnostic pattern appraisal by determining the extent of membership of individual symptoms. The model proposed allows for the classification of and matching of cluster groups to TB symptoms. The fuzzy- cluster means model proposed in this paper appears to be a more natural and intelligent way of classification and matching of symptoms to Tuberculosis groups.

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