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Interactive Neuro-Fuzzy Expert System for Diagnosis of Leukemia

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Abstracts - Leukemia is closely linked with the blood or bone marrow. Leukemia is regard as cancer of the blood cells (usually white blood cells). The abnormal white blood cells formed in leukemia also accumulate in the organs of the body such as the spleen, liver, lymph nodes, testes, and brain, and interfere with normal functioning of the organ. Leukemia is of four common type; Acute lymphocytic leukemia, acute myelogenous leukemia, chronic lymphocytic leukemia and chronic myelogenous leukemia. Leukemia symptoms are predominantly paleness, fatigue, bone pain, asthemia, palpitation, frequent infection, nose bleeding and thrombocytopenia. Neuro-Fuzzy Logic explores approximation techniques from neural networks to finds the parameter of a fuzzy system. In this paper, the traditional procedure for the medical diagnosis of leukemia employed by physician is analyzed using neuro-fuzzy inference procedure. From the system designed if the patient is having five or more of the enlisted symptoms, the patient is experiencing “severe Leukemia” and should go for treatment urgently. If it is approximately four of the symptoms the patient is experiencing, the patient “might be suffering from Leukemia” and hence should see a physician right away, but if it is three or less of the enlisted symptoms, the patient is not “suffering from Leukemia”. The system which demonstrates the practical application of Information and Communication Technology (ICT) in the health sector is interactive and tells the patient his current condition as regards Leukemia.

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I. Introduction

Knowledge-based expert systems, or simply expert systems, use human knowledge to solve problems that normally would require human intelligence. These expert systems represent the expertise knowledge as data or rules within the computer. These rules and data can be called upon when needed to solve problems. Books and manuals have a tremendous amount of knowledge but a human has to read and interpret the knowledge for it to be used. Most expert systems are developed via specialized software tools called shells. These shells come equipped with an inference mechanism (backward chaining, forward chaining, or both), and require knowledge to be entered according to a specified format (PCAI, 2000).

Leukemia (Cancer of the blood cells, usually white blood cells) is a type of cancer that occurs in the blood or bone marrow. Leukemia causes an uncontrolled growth of abnormal white blood cells, the infection fighting cells in the blood. Leukemia is one of the most common types of cancer and one of the top ten killers' cancers (Healthline, 2011 and Wrong Diagnosis, 2011)

Leukemia is a general term for four types of malignant disease of the blood and bone marrow (MedicineNet, 2011 and WrongDiagnosis, 2011). These include acute lymphocytic leukemia and acute myelogenous leukemia, which progress rapidly. The other forms of leukemia, chronic lymphocytic leukemia and chronic myelogenous leukemia, progress more slowly .

Leukemia is most treatable and curable if caught in the earliest stages of the disease. Untreated and/or advanced leukemia results in a proliferation of abnormal white blood cells that spread throughout the blood stream. These abnormal cells crowd out normal white blood cells. The abnormal white blood cells are not able to fight infections as effectively as the normal white blood cells. This results in increased infection (Wrong Diagnosis, 2011).

The abnormal white blood cells of leukemia also crowd out red blood cells, resulting in anemia, a low number of red blood cells. Leukemia also results in lower numbers of platelet cells in the blood, which are needed for normal clotting. This results in impaired clotting. The abnormal white blood cells formed in leukemia also accumulate in the organs of the body, such as the spleen, liver, spleen, lymph nodes, testes, and brain, and interfere with normal organ functioning (Best medicine, 2011).

Neural-Fuzzy is a fusion of neural network and fuzzy logic. Neuro-fuzzy system combines the advantages of both whilst eliminating their disadvantages. Using neuro-fuzzy logic the diagnosis of Leukemia will provide a self-learning intelligent system that is capable of handling uncertainties in the diagnosis process.

II. Literature Review

The cause of many cases of leukemia is unknown, but in some cases, leukemia is caused by abnormalities in the chromosomes. People at risk for developing leukemia include those who have been exposed to high doses of radiation, certain types of

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chemotherapy, or chemicals, such as benzene. Having Down syndrome or Fanconi's syndrome increases the risk as well. Additionally, certain viruses, such as Epstein-Barr virus, are associated with the development of leukemia. Smoking also increases the risk of leukemia (Wrong Diagnosis,2011 and Medicine Net, 2011).

Diagnosing leukemia begins with taking a thorough personal and family medical history, including symptoms and risk factors for leukemia. Diagnosis also includes completing a physical examination. Diagnostic testing includes a blood test called a complete blood count (CBC). A complete blood count will reveal the presence of high or low numbers of white blood cells, red blood cells and platelets. Other blood tests are also done to diagnose the specific type of leukemia. A bone marrow test is also done to diagnose leukemia. A bone marrow test involves using a needle to withdrawal a sample of cells from the bone marrow, where blood cells are formed. The sample is examined under a microscope for the presence of the abnormal leukemia cells. A diagnosis of leukemia can be missed or delayed because some symptoms of leukemia are similar to those of other conditions. In addition, some people may not have symptoms in early stages of some forms of leukemia. The prognosis for people with leukemia varies depending on the type of leukemia and other factors. However, many types of leukemia can be effectively treated and some can be cured. Survival rates for leukemia have risen dramatically in the last four decades due to improvements in treatment. Treatment of leukemia varies, depending on the specific type of leukemia, the patient's age, health history, overall health status, and other factors. Treatment may include chemotherapy, bone marrow transplant and enrollment in clinical trials (Bestmedicine, 2011; Healthline, 2011; MedicineNet, 2011 and Wrong Diagnosis, 2011).

Neural network (NN) consists of an interconnected group of neurons (Ponniyin, 2009). Artificial Neural Network (ANN) is made up of interconnecting artificial neurons (Programming constructs that mimic the properties of biological neurons). A Neural Network is an analog and parallel computing system. A neural network is made up of a number of very simple processing elements that communicate through a rich set of interconnections with variable weights or strength. ANN (subsequently referred to as NN) is used in solving artificial intelligence problems without creating a model of a real biological system. NN processes information using connectionist approach to computation. It changes it structures based on internal or external information that flows through the network during the learning phase. NN can be used to model complex relationship between input and output or find patterns in data. The term network in the term "Artificial Neural Network" arises because the function f(x) is defined as a composition of other function gi(x) which can further be defined as a composition of the other functions (Gary and George, 2002).

Figure 1 present a simple NN which comprises of three layers (Input, Hidden and Output layers).

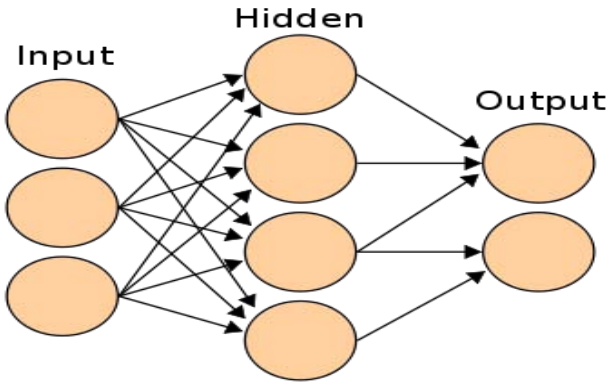

Figure 1: A simple Neural Network

The NN presented in Figure 1, comprises of a layer of "input" connected to a layer of "hidden" units, which is in turn connected to a layer of "output" units. The activity of the input unit represents the raw information that is fed into the network; the activity of the hidden units is determined by the activity of the input unit and the weights between the hidden and output units. The hidden units are free to construct their own representation of the input; the weights between the input and hidden units determine when each hidden unit is active, and so by modifying these weights, a hidden unit can choose what it represents (Christos and Dimitros, 2008).

NN employs learning paradigm that includes supervised, unsupervised and reinforcement learning (Wikipedia, 2010) NN has been applied in stock market prediction, credit assignment, monitoring the condition of machinery and medical diagnosis (Alesander and Morton, 1995; Bishop, 1995; Poa, 1989; Valid and Gholam, 2009 and Wikipedia, 2010). Application of NN in medical diagnosis includes electronic noses and diagonal of cardiovascular systems (Eklund and Fuller, 1993 and Wikipedia, 2010). NN are ideal in recognizing diseases using scans. They learn by example, hence details of how to recognize the disease is not needed. What is needed is set of examples that are representatives of all the variation of the disease. However, NN cannot handle linguistic information and also cannot manage imprecise or vague information (Akinyokun, 2002).

Fuzzy Logic (FL) is a branch of machine intelligence (Artificial Intelligence) that helps computers paint vivid pictures of the 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 helps 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 is called triangular fuzzy number (Figure 2) with peak (center) a, left width $\alpha>0$ and right width $\beta>0$ if its membership function has the form:

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

and we use the notation $A=(a, \alpha, \beta)$. It can easily be shown that

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

The support of A is $(a-\alpha, b+\beta)$.

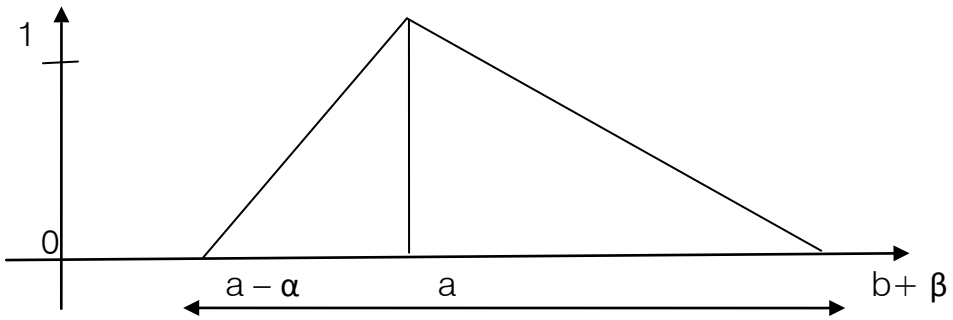

Figure 2 : Triangular Fuzzy Membership Number

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). 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.

Fuzzy Neural Network or Neuro-Fuzzy system is a learning machine that finds the parameters of a fuzzy system (i.e., fuzzy sets, fuzzy rules) by exploiting approximation techniques from neural networks (Statsoft Incorporated, 2008). Neuro-fuzzy refers to the combination of artificial neural network and fuzzy logic. It eliminates the individual weaknesses of neural network and fuzzy logic while making use of their best advantages. Fusion of neural network and fuzzy logic (that is Neuro-fuzzy) is interesting (Eklund and Fuller, 1993; Johnson, 1993; Kosaka, 1991; Nauck, 1996; Stathacopoulou et al., 2004 and Wong et al., 2002) Neuro-fuzzy system for the diagnosis of Leukemia disease will provide a self-learning and adaptive system that is able to handle uncertain and imprecise data.

III. Methodology

The process for the medical diagnosis of Leukemia 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 the 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 Leukemia 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 Leukemia. The examining physician accounts for possibilities of having Leukemia through an interview, physical examination and laboratory test. Many primary health care physicians may require tools for Leukemia evaluation.

Neuro-fuzzy inference procedure is applied to the diagnosis of Leukemia using the model prescribed in Figure 3. The Expert system using the neuro-fuzzy model 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-Solution and Crystal Report were used for Neural Networks analysis and graphical representation respectively.

IV. Result and Discussion

To design our neuro-fuzzy system for diagnosis of Leukemia, we designed a system which consists of a set of symptoms needed for the diagnosis (here, we are using fourteen basic and major symptoms):

(a). Paleness. (b). Shortness of breath. (c). Nose bleeding. (d). Frequent Infection.
(e). Anaemia. (f). Epistaxis. (g). Bone pain. (h). Thrombocytopenia.
(I). Granulocytopenia. (j). Asthemia. (k). Palpitations. (l.) Digestive bleeding.
(m). Enlarge Spleen. (n.) Fatigue.

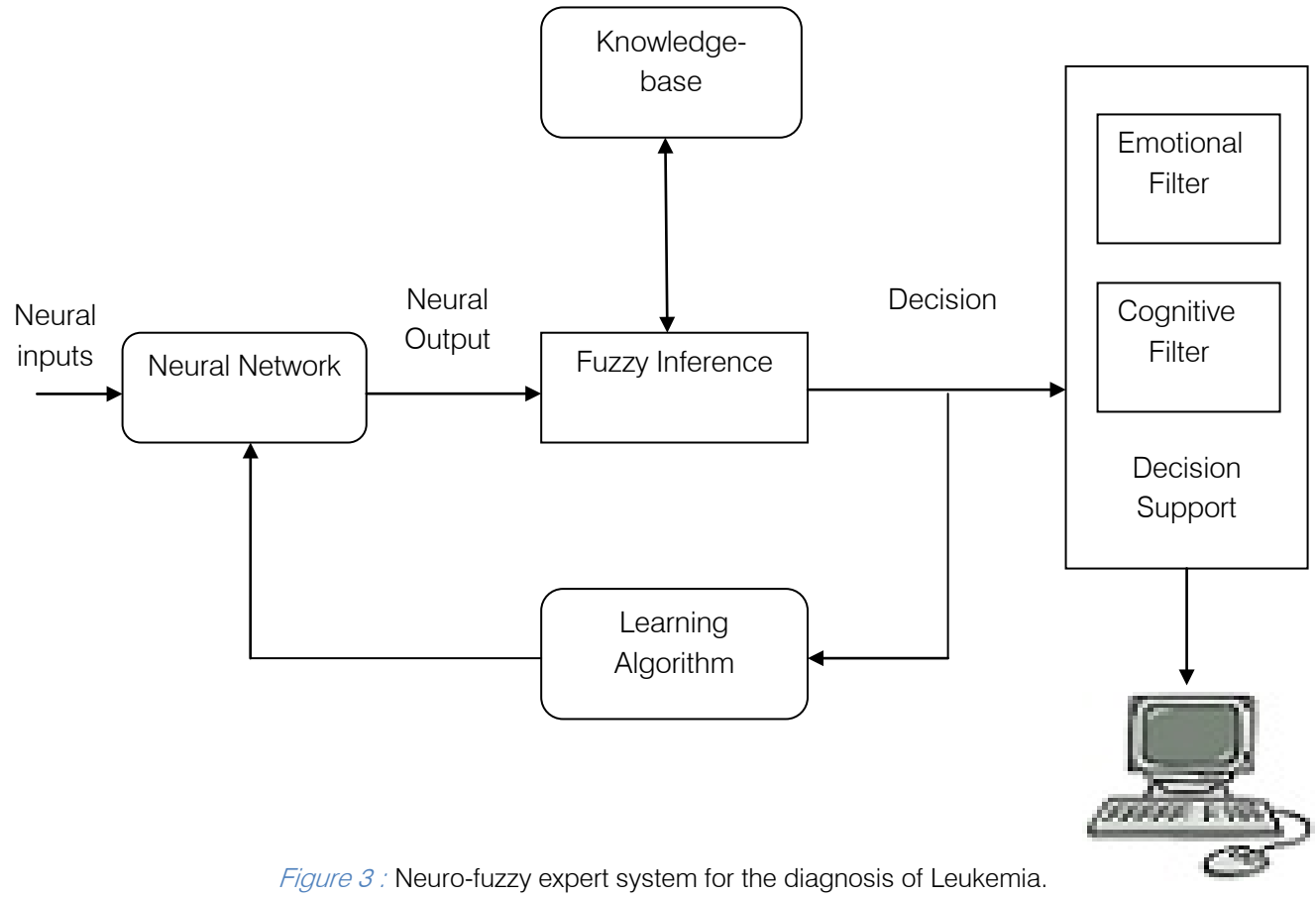

Figure 3 : Neuro-fuzzy expert system for the diagnosis of Leukemia.

The knowledge base consists of the database, which consist of fourteen basic parameters mentioned earlier. The values of the parameters are often vague (fuzzy) and imprecise hence the adoption of fuzzy logic in the model as means of analyzing these data. These parameters therefore constitute the fuzzy parameter of the knowledge base. 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 parameter (in this case n=14). The set of linguistic values which is modeled as a linker scale denoted by 'L' is given as L= {Low, Moderate and High}.

Neural networks provide the structure for the parameters, which serves as a platform for the inference engine. The inference engine consists of reasoning algorithm driven by production rules. These production rules are evaluated by using the forward chaining approach of reasoning (Nauck, 1996). The inference mechanism is fuzzy logic driven. The cognitive filter of the decision support engine takes as input the output report of the inference engine and applies the objective rules to rank the individual on the presence or absence of Leukemia disease. The emotional filter takes as input the output report of the cognitive filter and applies the subjective rules in the domain of studies in order to rank individuals on the extent of the Leukemia disease.

A universal set of symptoms of Leukemia disease is set up for diagnosis where the patient is expected to choose or pick from the set of symptoms fed into the system. We used a simple binary encoding scheme wherein the presence of a symptom is represented by 1 in the input vector and 0 otherwise (we call this the symptom vector).

The operational procedure of the model is represented in Figure 4. The set of symptoms are fed into the network. The patient is expected to choose from the list of symptoms the one corresponding to what he/she is having

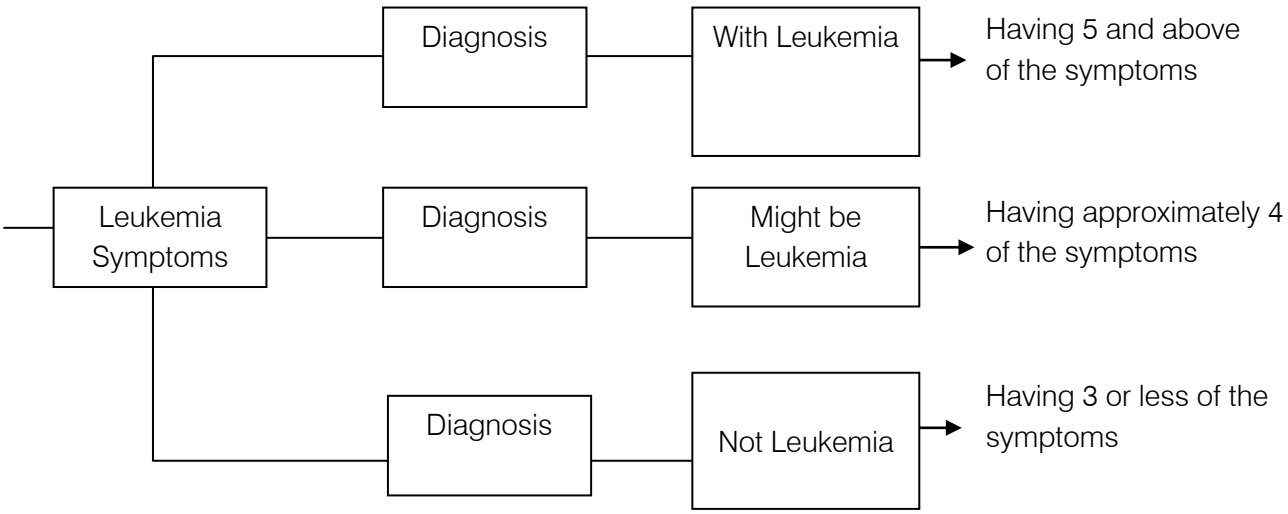

Figure 4 : Operational procedure of the neuro-fuzzy system for the diagnosis of Leukemia

If the patient is having five or more of the symptoms, he is having severe Leukemia and should go for treatment urgently. If it is approximately four of the symptoms he is having, he might be suffering from Leukemia and hence should see a physician right away, but if it is three or lesser of the symptoms, he may not be having Leukemia.

A typical data set that contains the fourteen symptoms is presented in Table 1. This shows the degree of intensity of the symptoms. As the value tends to 1.0, the more the chances that the patient is suffering from Leukemia

Table 1 : Data Set showing the degree of intensity of Leukemia Symptoms Scale (0.00 – 1.00)

SYMPTOMS	DEGREE OF INTENSITY		
Paleness	0.60	0.30	0.10
Shortness of Breath	0.30	0.55	0.15
Nose Bleeding	0.80	0.10	0.10
Frequent infection	0.68	0.15	0.17
Anaemia	0.32	0.60	0.08
Epistaxis	0.59	0.29	0.12
Bone pain	0.20	0.15	0.65
Thrombocytopenia	0.18	0.70	0.12
Granulocytopenia	0.50	0.50	0.00
Asthenia	0.60	0.20	0.20
Palpitation	0.55	0.25	0.20
Digestive Bleeding	0.77	0.13	0.10
Enlarge spleen	0.15	0.20	0.65
Fatigue	0.20	0.26	0.54
RESULT	With Leukemia	Might be Leukemia	Not Leukemia

Next, we create fuzzy logic membership functions that define the value of input/ output terms used in the rules. Membership functions are graphical function representation of the magnitude of the preparation of each input that is processed. Typical membership function is presented in Figure 5. Figure 6 shows that the height of the symptoms is 0.0, 0.5 or 1.0 and does not exceed 1.0. The fuzzy set however is zero, X/4 or one. From Figure 6, we say that when the fuzzy set is between zero and X/4, the person's condition is Low ("Not suffering from Leukemia"). When the fuzzy set is in-between zero and one, the condition is moderate ("might be suffering from Leukemia") and when it is between X/4 and one, the person's condition is high ("suffering from severe Leukemia").

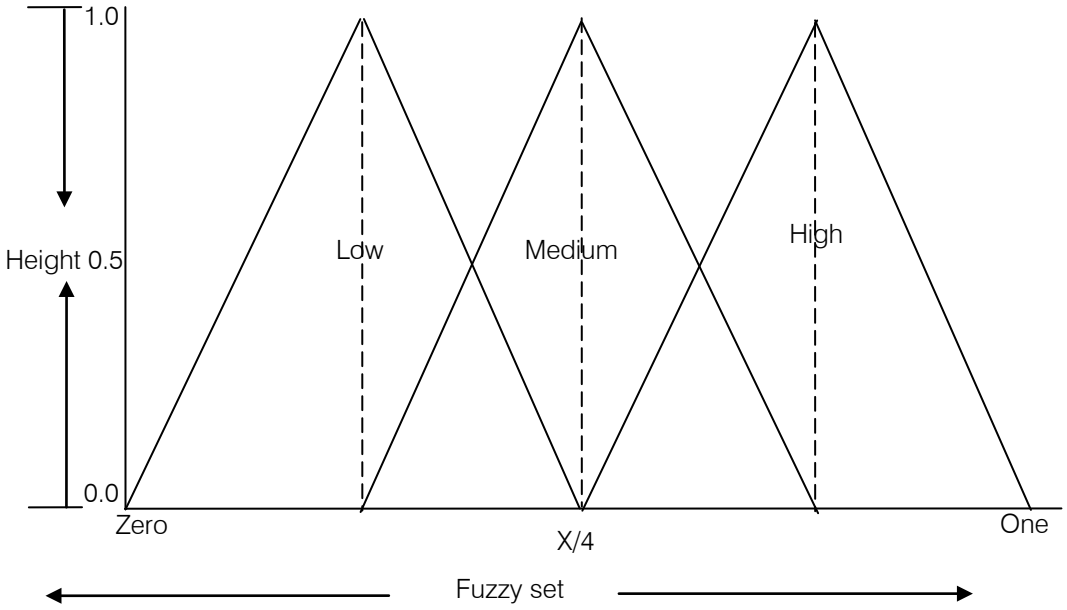

Figure 5 : Membership Function for Leukemia

Further, we create the necessary pre and post processing. As inputs are received by the system, the rule based is evaluated. The antecedent, which is the (IF X AND Y), block test the input and produces a conclusion. The consequent (THEN Z) are satisfied while the others may not be. The conclusion is combined to form logical sums. The degree of membership (D.O.M) of Leukemia is represented in Figure 6.

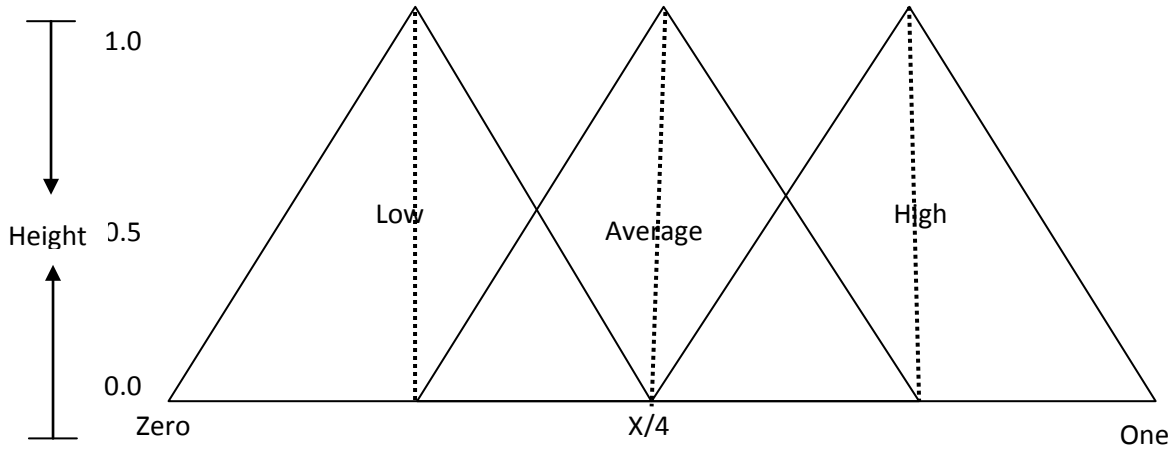

Figure 6 : Analysis of Leukemia Symptoms

Defuzzification coverts the rules base fuzzy output into non-fuzzy (numerical values). It reflects the interpretation of the logic of the different linguistic variable. The system can also be configured to handle not only Leukemia but, other kind of illness and diseases.

V. Conclusion

The need to design a system that would assist physician in medical diagnosis of Leukemia cannot be over emphasized. This paper which demonstrates the practical application of Information and Communication Technology (ICT) in the health sector, presented a hybrid Neuro–Fuzzy Expert System to help in diagnosis of Leukemia using a set of symptoms. This system which uses a set of fuzzified data set incorporated into neural network system is more precise than the traditional system. The system designed is an interactive system that tells the patient his current condition as regards Leukemia. It should however be noted that the system was not designed to give prescription of Leukemia drugs to patients but can also be expanded to do so in subsequent research. A system of this nature that has the ability to diagnose a person suffering from Leukemia should be introduced in health care delivery centers and hospitals to help ease the work of physicians.

References Références Referencias

1. Akinyokun O.C. (2002), "Neuro-fuzzy expert system for evaluation of human Resource performance", First Bank of Nigeria Endowment Fund lecture Federal University of technology, Akure, Nigeria.
2. Aleksander I. and Morton H. (1998), "An introduction to neural computing" 2nd Edition Computer Science press.
3. Andreas N. (2001), "Neuro-Fuzzy system", retrieved from http//:Neuro-Fuzzy System.html.
4. Bart K. and Satoru I. (1993), "Fuzzy Logic", retrieved from http//:Fortunecity .com/emachines/e11/86/fuzzylog.html.
5. Bishop C.M. (1995), "Neural Networks for pattern Recognition", Oxford University Press, United Kingdom.
6. Christos S. and Dimitros S. (2008), "Neural Network" retrieved from http// :docs.toc.com/doc/1505/neural-networks.
7. Edward C.H. (2010), "Article: The gorilla Connection" retrieved from http//: Nature.com/nature/journal/v467/n7314/full/467404a. html.
8. Eklund D. and Fuller R. (1993), "A Neural-Fuzzy Approach to medical Diagnostic" Gedemedic project, Abo Academy University, Development Centres heisnki, pp.210-225.
9. Gary R. and George P.E. (2002), "Application of Neuro System to behavior Representation in Computer generated forces", retrieved http//: Cuil.com.
10. Johnson R.C. (1993), "Making the Neural-Fuzzy Connection", Electronic Engineering Times, Cmp Publications, Manhasset, New York.
11. Kasra Karvandian et al., (2008) "Emergent Tracheostomy in Two Patients with Acute Leukemia", Comparing Surgical and Percutaneous Methods retrieved Journal of Medical Sciences 8 (1): 81 – 84.
12. Kosaka M. (1991), "Application of Fuzzy Logic/Neural Network to Securities Trading Decision Support", Conference Proceeding of the 1991 IEEE International Conference on Systems, man and Cybernetics, Vol.3, pp. 1913 – 1918.
13. Leondes C. (2010), "The Technology of Fuzzy Logic Algorithm retrieved from Suite101.com/examples-of-expert-System-application-in-artificial Intelligience.
14. MedicineNet, 2011, "Leukemia" retrieved from http"//MedicineNet.com
15. Nauck K. (1996), "Fuzzy Neural Network", http//:Wikipedia.org.
16. Pao Y.H. (1989), "Adaptive Pattern Recognition and Neural Network", Addison Wesley.
17. PCAI (2000), "Expert System: Introduction, retrieved from http:// PCAI.com/web/ai_info/expert.systems.html
18. Ponniyin S.K. (2009), "Neural Network", Icann2007.org/neural.networks.
19. Otuorimuo O. (2006), "Prototype of Fuzzy System for the Formulation and Classification of Poultry Feed", Bachelor of Science (Computer Science) Project, University of Benin, Benin City, Nigeria.
20. Rudolf K. (2008), "Article: Institute of Information and Communication System", Otto-Van-Guericke, University of Magdebury, Germany.
21. Rumelhert D.E.,Windrow B., and Lehr M.A (1994), "Neural Networks: Application in Industry, Business and Science", Communication of ACM, 37(1994), 93-105.
22. Saleh et al., (2010) "Identification of Genomic Markers by RAPD-PCR Primer in Leukemia Patients" retrieved from Biotechnology 9 (2): 170 – 175.
23. Srinivasan et al., (2006), "A Point of Care Clinical Decision Support System for the Diagnosis of Neonatal Jaundice by Medical Field Personnel " retrieved Journal of Applied Sciences 6 (5): 1003 – 1008.
24. Stathacopoulou R.,Magoulas G.D.,Grigoriadou M., and Samarakou M. 2004), "Neural-Fuzzy knowledge processing in Intelligent learning

Environment for Improved Student Diagnosis" DOI Information 10.1016/j.ins.2004.02.026.
25. Statsoft Incorporated (2008), "Neural Network" retrieved from http//: google.com.
26. Vahid K. and Gholam A.M. (2009), "Artificial Intelligence in medicines", V47 , Issues 1 Information Technology Department, School of Engineering, Terbiat Moderas University Tehran,Iran.
27. Wikipedia (2010), "Artificial Neural Network" retrieved from http//: en.Wikipedia.org/wiki/Artificial-neural-network.
28. Wong K., Fung C and Myers D. (2002), "An Integrated Neural Fuzzy Approach With reduced rules for well log analysis", International Journal of Fuzzy Systems 4(1) 592-599.
29. WrongDiagnosis (2011), "Leukemia", retrieved from http"//www.Wrongdiagnosis. com/l/leukemia/Introduction/symptoms.htm#sympt om_list
30. Zadeh L.A. (1965), "Fuzzy sets. Information and control, Vol.8, pp.338-353.
31. Zimmermann H.J. (1993), "Fuzzy sets, Decision making and expert system" International series in Management Science/Operation Research, University of Houston, U.S.A.