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FUZZY NEURAL APPROACH FOR COLON CANCER PREDICTION

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ABSTRACT
In this paper, the traditional procedure of the medical diagnosis of colon cancer employed by physician is analyzed using neuro-fuzzy inference procedure. The proposed system which is self-learning and adaptive is able to handle the uncertainties often associated with the diagnosis and analysis of colon cancer.

Key words: *Neural Network, Fuzzy logic, Neuro Fuzzy System, Expert System, colon cancer*

INTRODUCTION
Cancer is a group of more than 100 different diseases. They affect the body's basic unit, the cell. Cancer occurs when cells become abnormal and divide without control or order. Like all other organs of the body, the colon and rectum are made up of many types of cells. Normally, cells divide to produce more cells only when the body needs them. This orderly process helps keep us healthy, MedicineNet (2011) and Healthline (2011).

The colon is the part of the digestive system where the waste material is stored. The rectum is the end of the colon adjacent to the anus. Together, they form a long, muscular tube called the large intestine (also known as the large bowel). Tumors of the colon and rectum are growths arising from the inner wall of the large intestine. Benign tumors of the large intestine are called polyps. Malignant tumors of the large intestine are called cancers. Benign polyps do not invade nearby tissue or spread to other parts of the body. Benign polyps can be easily removed during colonoscopy and are not life-threatening, Healthline (2011). If benign polyps are not removed from the large intestine, they can become malignant (cancerous) over time. Most of the cancers of the large intestine are believed to have developed from polyps. Cancer of the colon and rectum (Figure 1); also referred to as colorectal cancer, BetterMedicine (2011), Healthline (2011) and MedicineNet (2011) can invade and damage adjacent tissues and organs. Cancer cells can also break away and spread to other parts of the body (such as liver and lung) where new tumors form. The spread of colon cancer to distant organs is called metastasis of the colon cancer. Once metastasis has occurred in colorectal cancer, a complete cure of the cancer is unlikely.

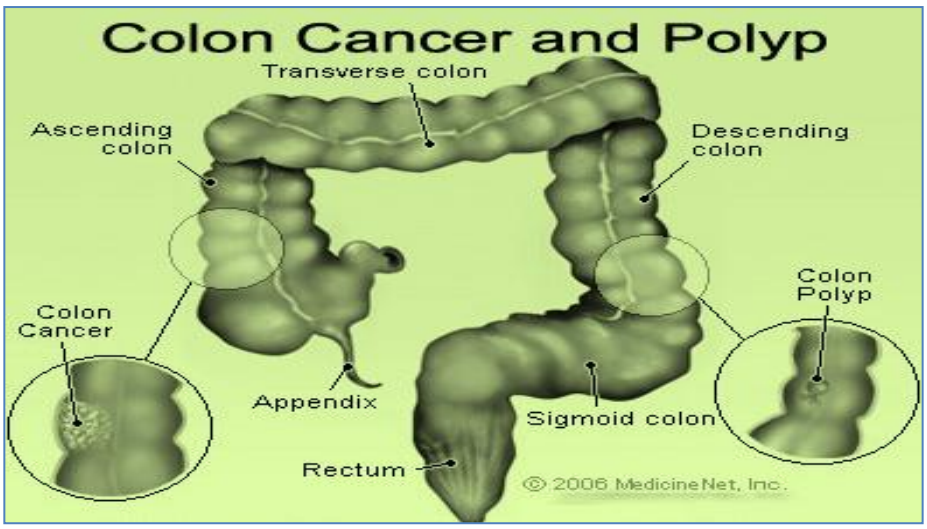

Figure 1: Pictorial representation of Colon Cancer and Polyp

Globally, cancer of the colon and rectum is the third leading cause of cancer in males and the fourth leading cause of cancer in females. The frequency of colorectal cancer varies around the world. It is common in the Western world and is rare in Asia and Africa. In countries where the people have adopted western diets, the incidence of colorectal cancer is increasing.

Factors that increase a person's risk of colorectal cancer include high fat intake, a family history of colorectal cancer and polyps, the presence of polyps in the large intestine, and chronic ulcerative colitis, MedicineNet (2011).

Symptoms of colon cancer are numerous and nonspecific. They include fatigue, weakness, shortness of breath, change in bowel habits, narrow stools, diarrhea or constipation, red or dark blood in stool, weight loss, abdominal pain, cramps, or bloating. Other conditions such as irritable bowel syndrome (spastic colon), ulcerative colitis, Crohn's disease, diverticulosis, and peptic ulcer disease can have symptoms that mimic colorectal cancer.

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) 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 $g_i(x)$ which can further be defined as a composition of the other functions, Gary and George (2002). Figure 2 presents a simple NN which comprises of three layers (Input, Hidden and Output layers).

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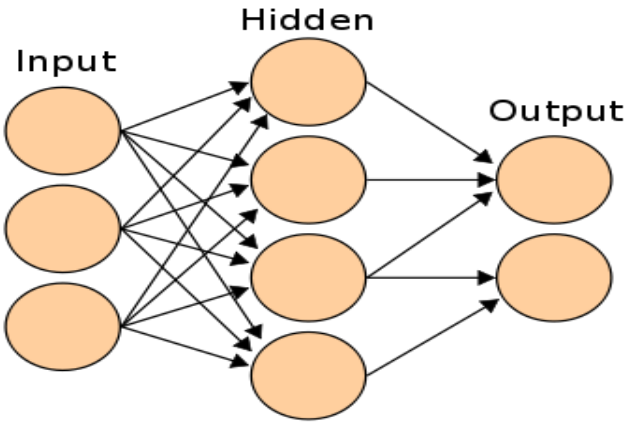

Figure 2: A simple Neural Network

The NN presented in Figure 2, 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, Dase and Pawar (2010); Hiroshi et al. (2011); Adyles and Fabrício, (2010); Vahid and Gholam, (2009) and Wikipedia, (2010). Application of NN in medical diagnosis includes electronic noses and diagnosis of cardiovascular systems, Jionghua et al, (2010) and, Wikipedia (2010) for the diagnosis of tuberculosis, Imianvan and Obi (2011) for the, diagnosis of Leukemia, Obi and Imianvan (2011), for the diagnosis of Breast Cancer, Obi and Imianvan (2011) and diagnosis of Alzheimer Obi and Imianvan (2011).

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) 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 A is called trapezoidal fuzzy number (Figure 3) 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 $(a - \alpha, b + \beta)$.

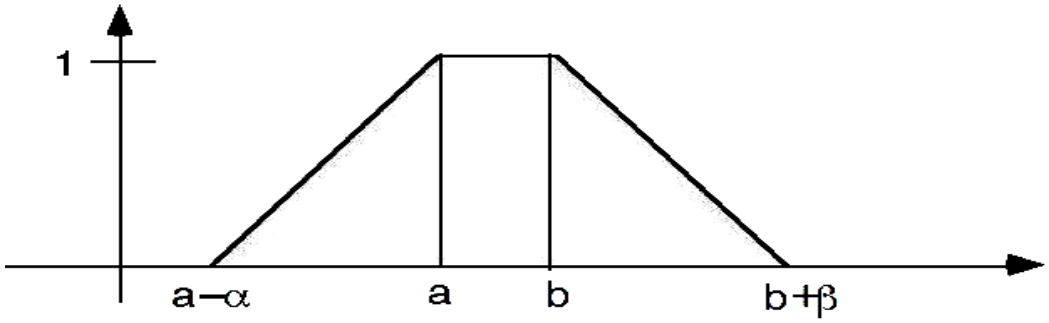

Figure 3: Trapezoidal fuzzy number

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. They 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, PCAI (2002); NIJ (2011) and Steffen (2011).

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) and 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 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 Jionghua et al, (2010); Saman (2010); Stathacopoulou et al., (2004). Neuro-fuzzy system for the diagnosis of colon cancer will provide a self-learning and adaptive system that is able to handle uncertain and imprecise data.

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MATERIALS AND METHODS

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

Neuro-fuzzy inference procedure is applied to the diagnosis of colon cancer using the model prescribed in Figure 4.

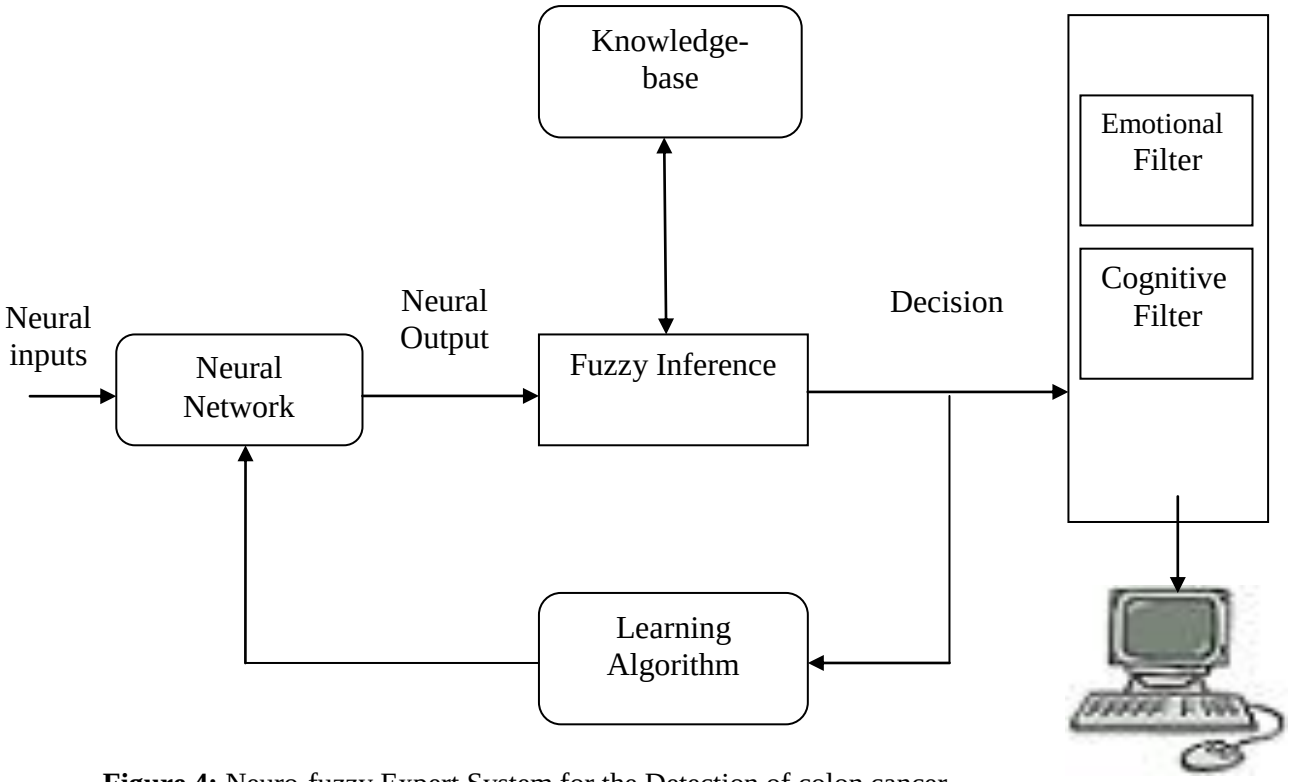

Figure 4: Neuro-fuzzy Expert System for the Detection of colon cancer.

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. The interaction between the user and the system is represented using Unified Modeling Language (UML) interaction in Figure 5

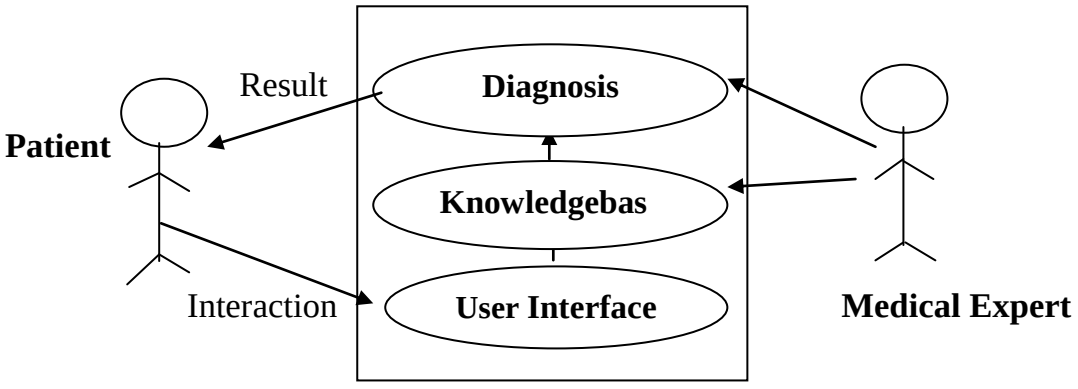

Figure 5: Use-case Diagram for patient-Doctor (Actors) Relationship

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RESULT

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

a. Severe abdominal pains
b. High fever (>101 degrees Fahrenheit)
c. Shortness of breath
d. Red or dark blood in stool
e. Constipation
f. Cramps or bloating.
g. Narrow stool
h. Weight loss
i. Change in level of alertness

The knowledge base consists of the database, which consist of nine 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=9). 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 (Georgios and Nick 2009 and Obi and Imianvan, 2011). 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 colon cancer. 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 colon cancer.

A universal set of symptoms of colon cancer 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 6. 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

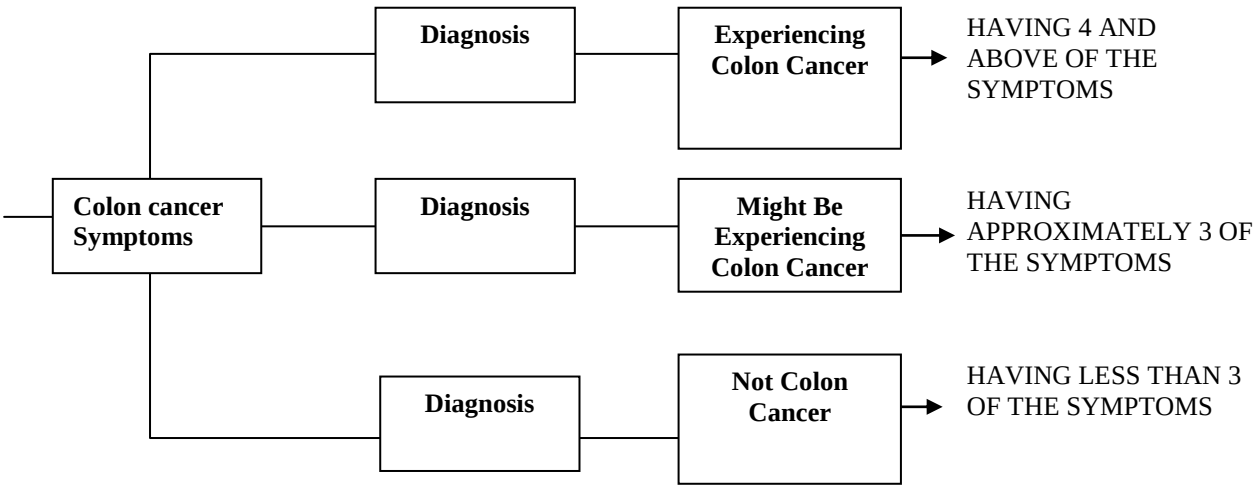

Figure 6: Operational Procedure of the Neuro-Fuzzy System for the Diagnosis of Colon cancer

If the patient is experiencing four or more of the clinical symptoms of colon cancer "*the patient is experiencing colon cancer"* and should go for treatment immediately. If it is approximately three of the clinical symptoms colon cancer "the patient *might be experiencing from colon cancer"*, but if it is less than three clinical symptoms of colon cancer, *"the patient is not experiencing colon cancer".*

Table 1: Data Set Showing the Degree of Intensity of Colon Cancer Symptoms Scale (0.00 – 1.00)

Symptoms (Parameters or Fuzzy Sets)	**Degree of Intensity of Colon Cancer**		
	Cluster 1 (C_1)	**Cluster 2 (C_2)**	**Cluster 3 (C_3)**
Severe Abdominal Pain	0.55	0.30	0.15
High fever (>101 degrees Fahrenheit)	0.80	0.10	0.10
Shortness of breath	0.68	0.15	0.17
Red or dark blood in stool	0.60	0.32	0.08
Constipation	0.29	0.59	0.12
Cramps or bloating.	0.20	0.65	0.15
Narrow stool	0.18	0.70	0.12
Weight loss	0.20	0.20	0.60
Change in level of alertness	0.15	0.30	0.55
RESULT	**Experiencing Colon Cancer**	**Might be Experiencing Colon cancer**	**Not Experiencing Colon Cancer**

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

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 7. Figure 7 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 7, we say that when the fuzzy set is between zero and X/4, the person's condition is Low ("Not colon cancer"). When the fuzzy set is in-between zero and one, the condition is moderate ("Might be Experiencing colon cancer") and when it is between X/4 and one, the person's condition is high ("Experiencing colon cancer").

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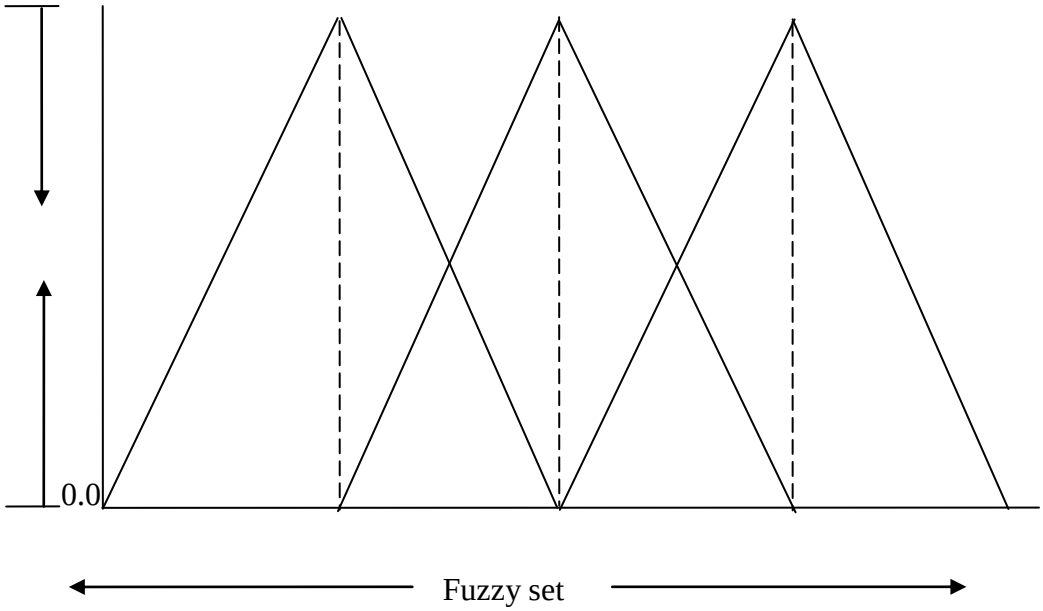

Figure 7: *Membership Function for colon cancer*

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.

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 colon cancer but, other kind of illness and diseases.

DISCUSSIONS

The need to design a system that would assist physician in medical diagnosis of colon cancer cannot be over emphasized. This paper which demonstrates the practical application of soft computing in the health sector, presents a hybridization of neural network and fuzzy logic to help in diagnosis of colon cancer 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 colon cancer. It should however be noted that the system was not designed to give prescription of colon cancer 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 colon cancer should be introduced in health care delivery centers and hospitals to help ease the work of physicians.

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