DIAGNOSTIC ANALYSIS OF BIPOLAR DISORDER USING NEURO-FUZZY LOGIC

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ABSTRACT: Bipolar disorder is also known as "bipolar" or "manic-depressive disorder". It is a serious mental disorder that manifests as periods of intense mania or euphoria that alternate with episodes of depression. The main cause of bipolar disorder is unknown but it is closely linked with genetic factors, malfunction of the brain neurons and hormonal deficiencies. In some cases bipolar disorder can be triggered by certain conditions, such as sleep deprivation, environmental factors, childhood precursors (antecedents), life event or experience, hypothyroidism, and the use of antidepressant medications. Combination of depression symptoms in conjunction manic symptoms gives the symptoms of bipolar disorder such as; distractibility, irritability, rebelliousness, grandiosity, racing thoughts persistent sad mood, Insomnia, feelings of worthlessness, inappropriate guilt and total loss of interest in activities. Neuro-Fuzzy Logic explores approximation techniques from neural networks to find the parameter of a fuzzy system. In this paper, the traditional procedure for the medical diagnosis of Bipolar disorder employed by physician is analyzed using Neuro-fuzzy inference procedure.

INTRODUCTION

Bipolar disorder was formally conceptualized by Emil Kraeplin more than 100 years ago, at which time it was described as manic-depressive insanity. However, mood problems that include depression alternating with symptoms that are now understood to be manic have been referenced in history as dating back to 200 A.D. At that time, this illness, like depression, was thought to be the result of bad blood, called black bile. In the 19th century, this illness was referred to by terms like biphasic illness, circular insanity, and dual-form insanity (MedicineNet, 2011).

Bipolar disorder is also known as "bipolar" or "manic-depressive disorder", MedicineNet, 2011 and WrongDiagnosis, 2011). It is a serious mental disorder that manifests as periods of intense mania or euphoria that alternate with episodes of depression. Bipolar disorder is classified as a mood disorder, which seriously affects a person's mood and interferes with a person's ability to function effectively in everyday life.

Below are some statistics about bipolar disorder:
a. Bipolar disorder is the fifth leading cause of disability worldwide.
b. Bipolar disorder is the ninth leading cause of years lost to death or disability worldwide.
c. The number of individuals with bipolar disorder who commit suicide is 60 times higher than that of the general population.
d. People who have bipolar disorder are at a higher risk of also suffering from substance abuse and other mental health problems.
e. Males may develop bipolar disorder earlier in life compared to females.
f. Blacks are sometimes diagnosed more often with bipolar disorder compared to whites.

The exact cause of bipolar disorder is often disputed but genetic link to the disorder is closely related. Most people with bipolar disorder have a close relative with the disorder or with depression. Bipolar disorder is sometimes associated with an imbalance of chemicals in the brain and hormonal deficiencies. In some cases bipolar disorder can be set off by certain conditions, such as sleep deprivation, environmental factors, childhood precursors, life event or experience, hypothyroidism, and the use of antidepressant medications. (WrongDiagnosis, 2011).

It is possible that a diagnosis of bipolar disorder can be missed or delayed because a person with the disorder may not seek care because of the stigma associated with mental illness. In addition, symptoms of bipolar disorder can be vague or associated with other conditions. Fuzzy logic helps paint vivid pictures of uncertain world. Neural networks are self-learning programs that mimics properties of biological neurons. 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 Bipolar disorder will provide a self-learning intelligent system that is capable of handling uncertainties in the diagnosis process.

Bipolar disorder is characterized by severe mood swings that also manifest in extremes in energy and functioning. Bipolar disorder includes period of intense mania, in which a person's mood is extremely elevated, and there is a very high level of energy, alertness and excitability. Symptoms also include impulsivity, racing thoughts and rapid talking. Complications of this phase of bipolar disorder include the development of delirium or paranoia. In bipolar disorder these periods of mania alternate with episodes of depression. Symptoms of depression include intense, overwhelming persistent feelings of sadness, despair, a low energy level, and difficulty concentrating. Depression can lead to suicidal thoughts and in extreme cases, suicide attempts (HealthLine, 2011). Combination of both symptoms of mania and depression will yield the symptoms of bipolar disorder.

The list of types of Bipolar disorder mentioned in various sources includes:
a.   Bipolar I disorder - recurrent episodes of mania and depression
b.   Bipolar II disorder - episodes of mild mania (hypomania) and depression
c.   Rapid-cycling bipolar disorder – with four or more episodes a year

Some people with bipolar disorder may experience a combination of symptoms of mania and depression. This is called a mixed state. During a mixed state, symptoms often include agitation, trouble sleeping, major changes in appetite, and suicidal thinking. People in a mixed state may feel very sad or hopeless while feeling extremely energized. In addition, some people with bipolar disorder can experience a rapid shifting from symptoms of mania to symptoms of depression. This is called rapid cycling (WrongDiagnosis, 2011).

Severe depression,   Normal or   Hypomania and
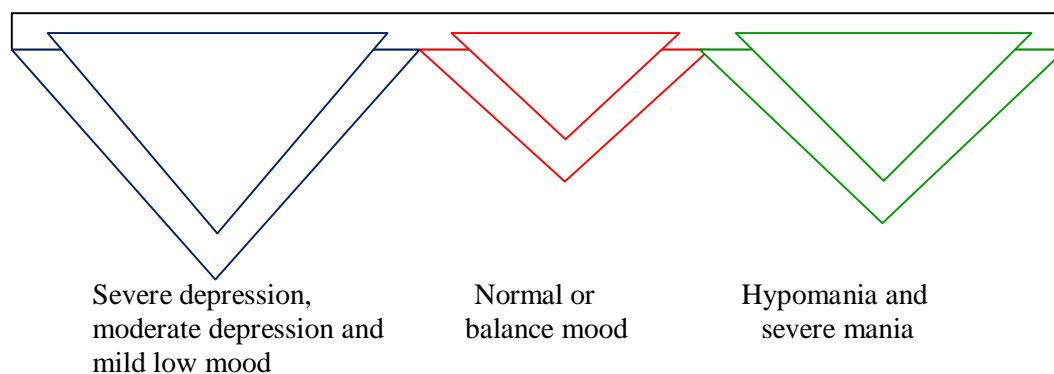moderate depression and   balance mood   severe mania
mild low mood

Figure 1: Scale for Severe depression, normal mood and severe mania

The left hand side of Figure 1 shows severe depression, moderate depression, and mild low mood. Moderate depression may cause less extreme symptoms, and mild low mood is called dysthymia when it is chronic or long-term. In the middle of the scale is normal or balanced mood (MedicineNet, 2011 and WrongDiagnosis, 2011).

The right hand side of Figure 1 shows hypomania and severe mania. Some people with bipolar disorder experience hypomania. During hypomanic episodes, a person may have increased energy and activity levels that are not as severe as typical mania, or he may have episodes that last less than a week and do not require emergency care. A person having a hypomanic episode may feel very good, be highly productive, and function well. This person may not feel that anything is wrong even as family and friends recognize the mood swings as possible bipolar disorder. Without proper treatment, however, people with hypomania may develop severe mania or depression.

Sometimes, a person with severe episodes of mania or depression has psychotic symptoms too, such as hallucinations or delusions (HealthLine, 2011). The psychotic symptoms tend to reflect the person's extreme mood. For example, psychotic symptoms for a person having a manic episode may include believing he is famous, has a lot of money, or has special powers. In the same way, a person having a depressive episode may believe he is ruined and penniless, or has committed a crime. As a result, people with bipolar disorder who have psychotic symptoms are sometimes wrongly diagnosed as having schizophrenia, another severe mental illness that is linked with hallucinations and delusions (WrongDiagnosis, 2011).

There is no specific test that can diagnose bipolar disorder. Making a diagnosis of bipolar disorder begins with taking a thorough medical history, including symptoms, and completing a physical examination and mental health exam. Assessment and tests are also performed to ensure that symptoms are not due to treatable medical conditions, such as hypothyroidism, hyperthyroidism, sleep deprivation, or the side effect of medications, such as antidepressants or thyroid medications. A referral to a psychiatrist or other licensed mental health provider is generally made to aid in the diagnosis and treatment of bipolar disorder.

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 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 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 comprise of three layers (Input, Hidden and Output layers). 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)
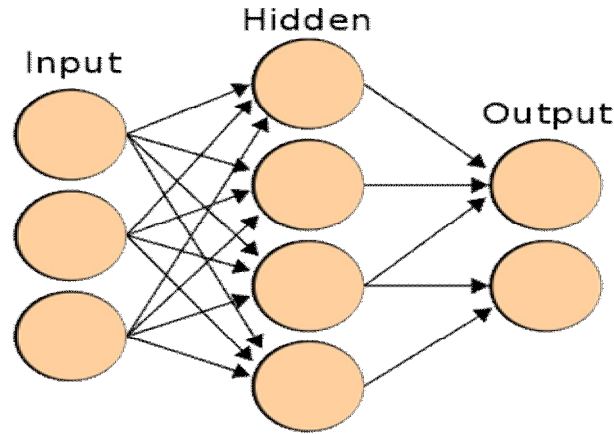
Figure 2: A simple Neural Network

NN employs learning paradigm that includes supervised, unsupervised and reinforcement learning (Wikipedia, 2010).

Application of NN in medical diagnosis includes electronic noses and diagnosis of cardiovascular systems (Eklund and Fuller, 1993 and Wikipedia, 2010). NN are ideal in recognizing diseases using scans (Preis, 2011). 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 is called triangular fuzzy number (Figure 3) with peak (center) a, left width $\alpha > 0$ and right width $\beta > 0$ if its membership function has the form:

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

and we use the notation is $A = (a, \alpha, \beta)$ such that

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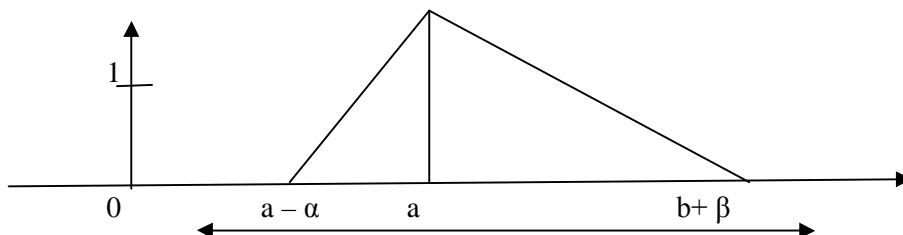

Figure 3: Triangular Fuzzy Membership

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 is a learning machine that finds the parameters of a fuzzy system by exploiting approximation techniques from neural networks (Statsoft, 2008).

METHODOLOGY
The process for the medical diagnosis of bipolar disorder starts when an individual consults a physician and presents a set of complaints. 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 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 the patients' illness. These are usually ranked possibilities the order (low, moderate and high). The physician then conducts a physical examination of the patient, studies his 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 scheduled such as medical imaging, scan, X-rays in part to confirm or disprove the diagnosis or to update the patient medical history. Other experts in the field may be consulted for further advices.

Despite 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 completion of the diagnosis, a treatment plan is proposed, which includes therapy and follow-up. Review of diagnosis may be conducted again if there is failure of the patient to respond to treatment that would normally work. The examining physician accounts for possibilities of having bipolar disorder through an interview, physical examination and laboratory test. Many primary health care physicians may require tools for bipolar disorder evaluation.

Neuro-fuzzy inference procedure is applied to the diagnosis of bipolar disorder using the model prescribed in Figure 4. The 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.
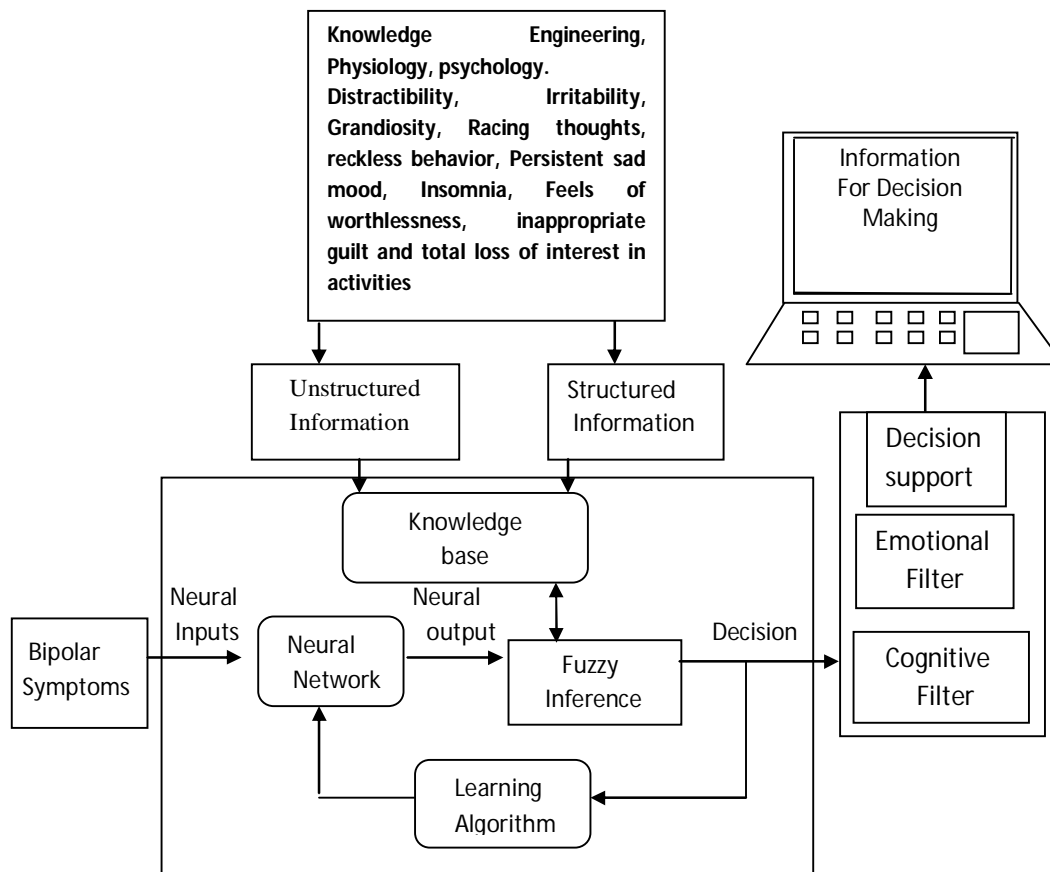
RESULT AND DISCUSSION

Figure 4: Model of the Neuro-Fuzzy Expert system for Bipolar disorder

The knowledge base consists of the database, which consist of ten 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 jth parameter and n is the number of parameter (in this case n=10). The set of linguistic values which is modelled 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 Bipolar disorder. 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 Bipolar disorder.

To design our neuro-fuzzy system for diagnosis of bipolar disorder, we designed a hybrid system which consists of a set of symptoms (mania and depression) needed for the diagnosis (here, we used ten basic and major symptoms):

Mania Symptoms (MS)		*Depression Symptoms (DS)*	
a.	Distractibility	f.	Persistent sad mood
b.	Irritability	g.	Insomnia
c.	Rebelliousness	h.	Feels of worthlessness
d.	Grandiosity	i.	inappropriate guilt
e.	Racing thoughts	j.	Total loss of interest in activities

The universal set of symptoms for bipolar disorder is used for the 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 5. The patient is expected to choose from the list of symptoms the one corresponding to what he is having.
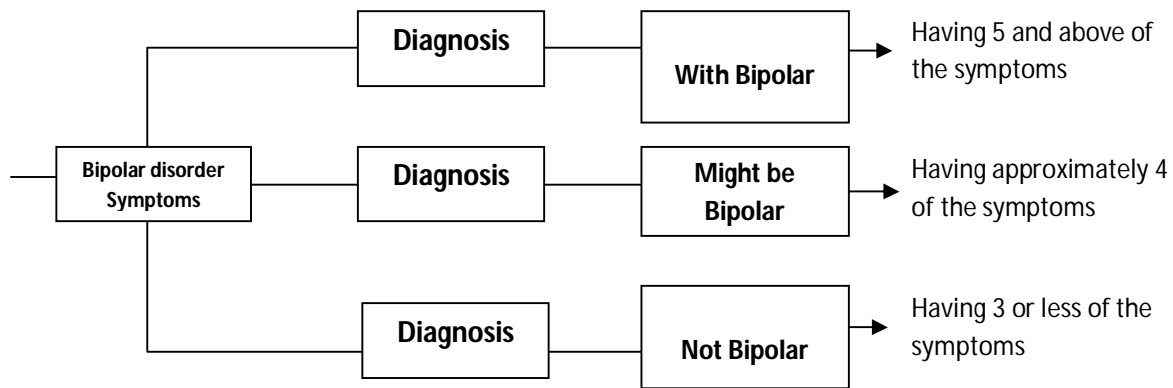

Fig. 5: Operational procedure of the Neuro-Fuzzy system for the diagnosis of bipolar disorder.

A typical data set that contains the ten 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 the patient is suffering from bipolar disorder. If the patient is having five or more of the symptoms, he is having severe "bipolar disorder" and should go for treatment urgently. If it is approximately four of the symptoms he is having, he might be suffering from "bipolar disorder" and hence should see a physician right away, but if it is three or lesser of the symptoms, he may not be having "bipolar disorder".

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

SYMPTOMS	DEGREE OF INTENSITY		
Distractability	0.60	0.30	0.10
Irritability	0.30	0.55	0.15
Rebelliousness	0.80	0.10	0.10
Grandiosity	0.68	0.15	0.17
Racing thoughts	0.32	0.60	0.08
Persistent sad mood	0.18	0.70	0.12
Insomnia	0.50	0.50	0.00
Feeling of worthlessness	0.60	0.20	0.20
Inappropriate guilt	0.20	0.25	0.55
Total loss of interest in activities	0.77	0.13	0.10
RESULT	With Bipolar	Might be Bipolar	Not Bipolar

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 6. 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 suffering from Bipolar disorder").

When the fuzzy set is between zero and one, the condition is moderate ("might be suffering from Bipolar disorder") and when it is between X/4 and one, the person's condition is high ("suffering from severe Bipolar disorder"). 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 (DOM) of Bipolar disorder is represented in Figure 6.
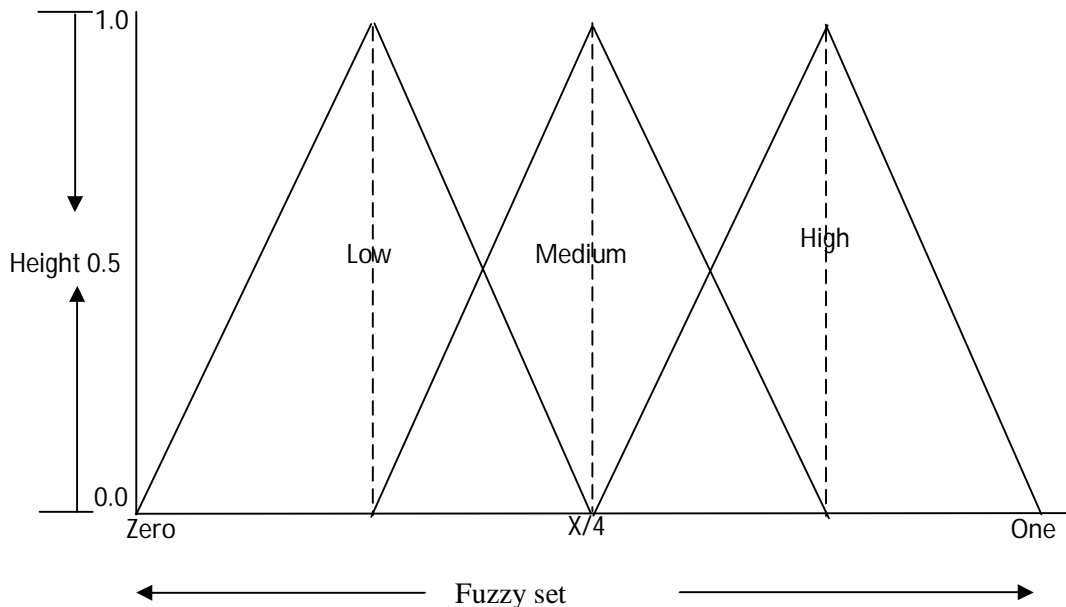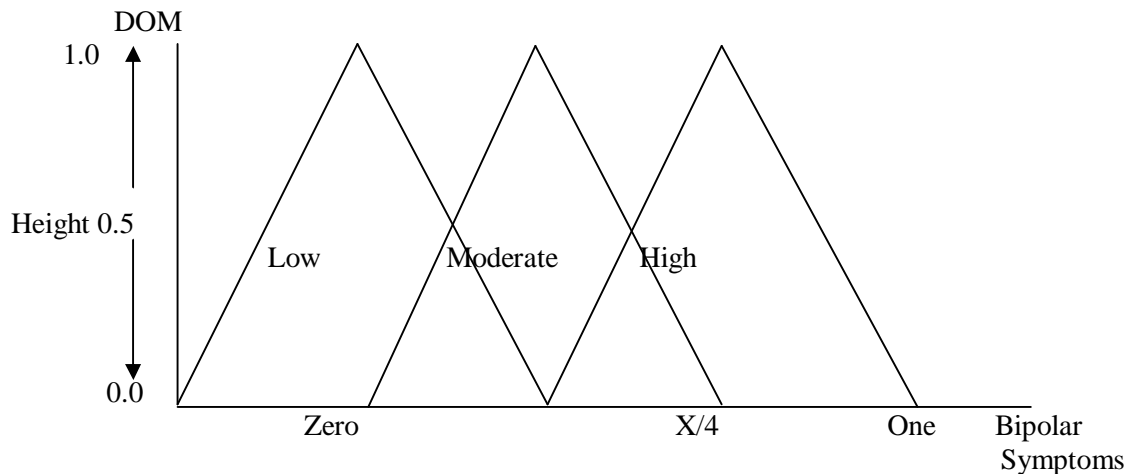

Figure 6: Membership Function for Bipolar disorder

Figure 7: Analysis of Bipolar disorder

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 Bipolar disorder but, other kinds of illness and diseases.

CONCLUSION
The need to design a system that would assist physician in medical diagnosis of Bipolar disorder cannot be over emphasized. This paper has demonstrated the practical application of Information and Communication Technology in the health sector, presented a hybrid Neuro-Fuzzy Expert System to help in diagnosis of Bipolar disorder 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 Bipolar disorder. It should however be noted that the system was not designed to give prescription of Bipolar disorder 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 Bipolar disorder should be introduced in health care delivery centers and hospitals to help ease the work of physicians.

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