Cognitive Neuro-Fuzzy Expert System for Hypotension Control

Imianvan Anthony Agboizebeta   (Corresponding author)
Department of Computer Science, University of Benin, Benin City. Nigeria.
PO box 1154, Benin City, Nigeria
Tel: +234(0)7069742552 E-mail: tonyvanni@yahoo.com

Obi Jonathan Chukwuyeni
Department of Computer Science, University of Benin, Benin City. Nigeria.
PO box 1154, Benin City, Nigeria
Tel: +234(0)8093088218 E-mail: tripplejo2k2@yahoo.com

Abstract

Hypotension; also known as low blood sugar affect gender of all sort; hypotension is a relative term because the blood pressure normally varies greatly with activity, age, medications, and underlying medical conditions. Low blood pressure can result from conditions of the nervous system, conditions that do not begin in the nervous system and drugs. Neurologic conditions (condition affecting the brain neurons) that can lead to low blood pressure include changing position from lying to more vertical (postural hypotension), stroke, shock, lightheadedness after urinating or defecating, Parkinson's disease, neuropathy and simply fright. Clinical symptoms of hypotension include low blood pressure, dizziness, Fainting, clammy skin, visual impairment and cold sweat. Neuro-Fuzzy Logic explores approximation techniques from neural networks to find the parameter of a fuzzy system. In this paper, the traditional procedure of the medical diagnosis of hypotension 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 hypotension.
Keywords: Neural Network, Fuzzy logic, Neuro Fuzzy System, Expert System, Hypotension

1. Introduction

Hypotension is a hybrid of the Greek "hypo" meaning "under" and the Latin "tensio" meaning "to stretch."Hypotension simply means blood pressure that is below the normal expected for an individual in a given environment (MedicineNet, 2011). Hypotension is the opposite of hypertension (abnormally high blood pressure). Orthostatic hypotension (OH) also known as hypotension describes an extreme drop in blood pressure that may result when a person stands up suddenly and the blood pools in the blood vessels of the legs. Because of this pooling, the amount of blood carried back to the heart by the veins is decreased. Subsequently, less blood is pumped out from the heart, resulting in a sudden drop in blood pressure. Conventionally, the drop in blood pressure must be greater than 20 mm of mercury during contraction of the heart muscles (systole) and more than 10 mm of mercury during expansion of the heart muscles (diastole). Among children and teenagers, short-lived episodes of OH are normal and not uncommon (WebMd, 2011). Episodes among the elderly are always to be taken seriously.

Normally, specialized cells in the body (baroreceptors) quickly respond to changes in blood pressure. These baroreceptors then activate the autonomic nervous system to increase, via reflex action, levels of catecholamines (e.g. epinephrine, norepinephrine) in the body. Increased catecholamine levels rapidly restore the blood pressure. A defect in this spontaneous response (reflex) prevents the heart rate and blood pressure from rising adequately and orthostatic hypotension results (WebMd, 2011).

Hypotension is a relative term because the blood pressure normally varies greatly with activity, age, medications, and underlying medical conditions. Low blood pressure can result from conditions of the nervous system, conditions that do not begin in the nervous system and drugs. Neurologic conditions(condition affecting the brain neurons) that can lead to low blood pressure include changing position from lying to more vertical (postural hypotension), stroke, shock,

lightheadedness after urinating or defecating, Parkinson's disease, neuropathy and simply fright (Healthline, 2011 and MedicineNet,2011). Non neurologic conditions that can cause low blood pressure include bleeding, infections, dehydration, heart disease, adrenal insufficiency, pregnancy, prolonged bed rest, poisoning, toxic shock syndrome, and blood transfusion reactions (Healthline, 2011 and WrongDiagnosis).

Clinical symptoms of hypotension include low blood pressure, dizziness, Fainting, clammy skin, visual impairment and cold sweat.

2. **Literature Review**

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 $g_i(x)$ which can further be defined as a composition of other functions (Gary and George, 2002).

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

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 (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). 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 2) with tolerance interval [a, b], left width α and right width β if its membership function has the following form

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

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

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

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 <u>learning machine</u> that finds the parameters of a <u>fuzzy system</u> (i.e., <u>fuzzy sets</u>, <u>fuzzy rules</u>) by exploiting approximation techniques from <u>neural networks</u> (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 hypotension will provide a self-learning and adaptive system that is able to handle uncertain and imprecise data.

3.   Methodology

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

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

a.   Low blood pressure
b.   Dizziness
c.   Fainting

d.   Visual impairment

e.   Cold sweat

f.   Chest pain

g.   General body weakness

h.   Clammy skin

.

The knowledge base consists of the database, which consist of eight 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= $\{P_1, P_2\dots, P_n\}$ where P_i represents the jth parameter and n is the number of parameter (in this case n=8). 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 hypotension. 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 hypotension.

Neuro-fuzzy inference procedure is applied to the diagnosis of hypotension 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. Unified modeling Language was used to model some of the functionalities in the system. UML is an excellent tool for modeling objects and the relationship between objects and classes (Djam and Kimbi 2011). The UML approach helps to depict the system in many different views thus giving a quick structural representation of the system. In this paper the sequence diagram was explored.

The objects interact as shown in the sequence diagram in Figure 4 below by passing messages across the timelines represented by arrows.

A universal set of symptoms of hypotension 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 5. 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.

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

4.   Results

A typical data set that contains the eight symptoms is presented in Table 1. This shows the degree of intensity of hypotension symptoms. As the value tends to 1.0, the more the chances that the patient is suffering from hypotension. The graphical representation in **Figure 6,** is a representation of Table 1 and clearly show ten clinical symptoms with high degree of "Experiencing Hypotension" in Cluster 1, four clinical symptoms with high degree of "Might   be experiencing Hypotension" in Cluster 2 and a symptom with high degree of "Not experiencing Hypotension" in Cluster 3.

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

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 hypotension but, other kind of illness and diseases.

5. Conclusion

Hypotension is becoming is a global health problem. The need to design a system that would assist physician in medical diagnosis of hypotension cannot be over emphasized. This paper which demonstrates the practical application of soft computing (combination of artificial intelligence, fuzzy logic and probabilistic reasoning) in the health sector, presents a hybridization of neural network and fuzzy logic to generate Neuro–Fuzzy Expert System to help in diagnosis of hypotension 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 hypotension. It should however be noted that the system was not designed to give prescription of hypotension 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 hypotension should be introduced in health care delivery centers and hospitals to help ease the work of physicians.

References

Adyles A. J., Fabrício C. L. A. (2010), "Automatic Faults Diagnosis by Application of Neural Network System and Condition-based Monitoring Using Vibration Signals" retrieved from
http://www.informatics.org.cn/doc/ucit201001/ucit20100104.pdf

Ahmad H. (2011), "Fuzzy approach to Likert Spectrum in Classified levels in surveying researches" retrieved
http://www.tjmcs.com

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.

Andreas N. (2001), "Neuro-Fuzzy system", retrieved from http//:Neuro-Fuzzy System.html.

Angel C. and Rocio R. (2011), "Documentation management with Ant colony Optimization
Metaheuristic: A Fuzzy Text Clustering Approach Using Pheromone trails" retrieved from soft   computing
in Industrial applications, Advances in intelligient and soft Computing, 2011 vol. 96, 2011, 261-70, DOI:
10.1007/978-3-642-20505-1_23

Bart K. and Satoru I. (1993), "Fuzzy Logic", retrieved from
    http//:Fortunecity   .com/emachines/e11/86/fuzzylog.html.

Christos S. and Dimitros S. (2008), "Neural Network" retrieved from
http//:docs.toc.com/doc/1505/neural-networks.

Dase R.K. and Pawar D.D. (2010), "Application of Neural network to stock market prediction: A review of literature", retrieved from http://www.bioinfo.in/uploadfiles/12843156482_2_3_IJMI.pdf

Djam X. Y. and Kimbi Y. H. (2011), "Fuzzy Expert System for the Management of Hypertension" retrieved from
//www.akamaiuniversity.us/PJST12_1_390.pdf

Edward C.H. (2010), "Article: The gorilla Connection" retrieved from http//:
  Nature.com/nature/journal/v467/n7314/full/467404a.html.

Gary R. and George P.E. (2002), "Application of Neuro System to behavior   Representation in Computer generated forces", retrieved http//: Cuil.com

Georgios M and Nick B. (2009), "DLEJena: A Practical Forward-Chaining OWL 2 RL Reasoner Combining Jena and Pellet" retrieved from DLEJena: A Practical Forward-Chaining OWL2 RL Reasoner Combining Jena and Pellet.

Healthline, (2011), "Hypotension", retrieved from healthline.com

Hiroshi S.; Kentaro K.; Kazuo O. and Masato O. (2011), "Statistical mechanics of Structural and temporal credit

assignment effects on learning in neural Networks" retrieved from http://pre.aps.org/abstract/PRE/v83/i5/e051125.

Jionghua T.; Suhuan W.; Jingzhou Z. and Xue W. (2010), "Neuro-fuzzy logic based fusion algorithm of medical images" retrieved from http:// ieeexplore.ieee.org /xpl./freeabs_all.jsp ?arnumber=5646958

Leondes C. (2010), "The Technology of Fuzzy Logic Algorithm retrieved from Suite101.com/examples-of-expert-System-application-in-artificial Intelligience.

MedicineNet (2011), "Hypotension" retrieved from http"//MedicineNet.com

NIJ: National Institute of Justice (2011), "Expert system technologies for criminal justice application" retrieved from https://www.ncjrs.gov/pdffiles1/nij/sl000959.pdf

Obi J. C. and Imianvan A.A. (2011), "Decision Support System for the Intelligient Identification of Alzheimer using Neuro Fuzzy logic" retrieved from http://airccse.org/journal/ijsc/papers/2211ijsc03.pdf

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.

PCAI (2000), "Expert System: Introduction, retrieved from http://PCAI.com/web/ai_info/expert.systems.html

Ponniyin S.K. (2009), "Neural Network", Icann2007.org/neural.networks.

Robert fuller (1995) "Neuro-fuzzy systems" www.scribd.com/.../flexible-neuro-fuzzy-Systems-Structures-Learning-and-Performance-Evaluation-Leszek-Rutkowski.

Rudolf K. (2008), "Article: Institute of Information and Communication System", Otto-Van-Guericke, University of Magdebury, Germany.

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.

Saman K. H. (2010), "Neuro-Fuzzy Systems from the Neural Network Perspective" retrieved from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.39.857

Srinivasan S.; Mital D.P. and Haque S. (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.

Stathacopoulou R.,Magoulas G.D.,Grigoriadou M., and Samarakou M. (2004), "A Neuro-Fuzzy Approach to Detect Student's Motivation" retrieved from http:// et.teiath.gr/English/cv/cv_samarakou.html

Statsoft Incorporated (2008), "Neural Network" retrieved from http//: google.com.

Steffen L. (2011), "Expert system and local Computation", University of Oxford, Graduate Lectures Hilary Term 2011

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.

WebMd (2011), "Hypotension" retrieved from webMd.com

Wikipedia (2010), "Artificial Neural Network" retrieved from http//en.Wikipedia.org/wiki/Artificial-neural-network.

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.

WrongDiagnosis (2011), "Hypotension", retrieved from http:// www. Wrongdiagnosis. com/l/PTSD/Introduction/symptoms.htm#symptom_list

Zadeh L.A. (1965), "Fuzzy sets. Information and control, Vol.8, pp.338-353.

Zimmermann H.J. (1993), "Fuzzy sets, Decision making and expert system" International series in Management Science/Operation Research, University of Houston, U.S.A.

Notes

Table 1: *Data Set showing the Degree of Intensity of hypotension Symptoms.*   *Scale (0.00 – 1.00)*

SYMPTOMS (FUZZY SETS)	CODES	DEGREE OF INTENSITY OF HYPOTENSION		
		Cluster 1(C_1)	Cluster 2(C_2)	Cluster 3(C_3)
Low blood Pressure	P01	0.55	0.30	0.15
Dizziness	P02	0.80	0.10	0.10
Fainting	P03	0.68	0.15	0.17
Visual impairment	P04	0.60	0.32	0.08
Cold sweat	P05	0.29	0.59	0.12
Chest pain	P06	0.20	0.65	0.15
General body weakness	P07	0.18	0.70	0.12
Clammy skin	P08	0.20	0.20	0.60
RESULT		Experiencing Hypotension	Might be Experiencing Hypotension	Not Experiencing Hypotension
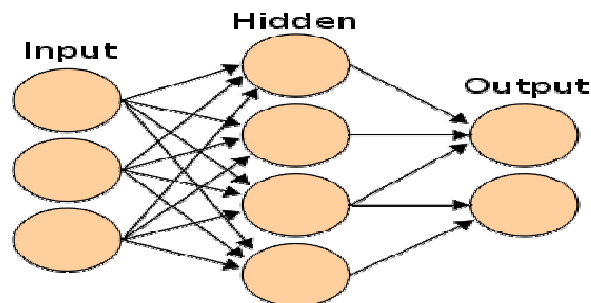
Figure 1*: A simple Neural Network*

The support of A is (a − α, b + β).
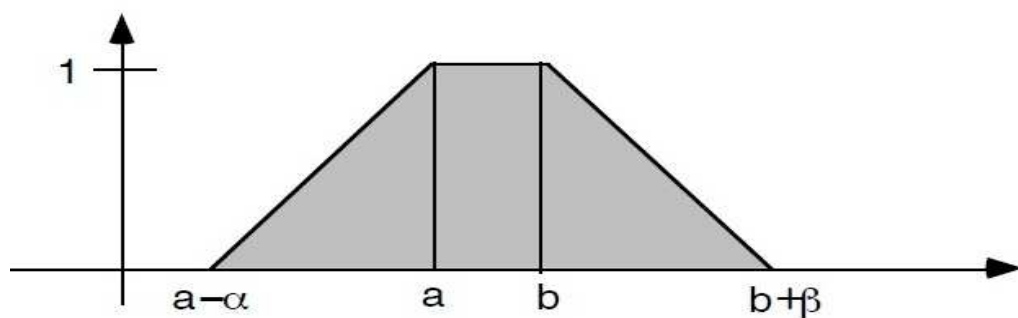
Figure 2: *Trapezoidal fuzzy number*
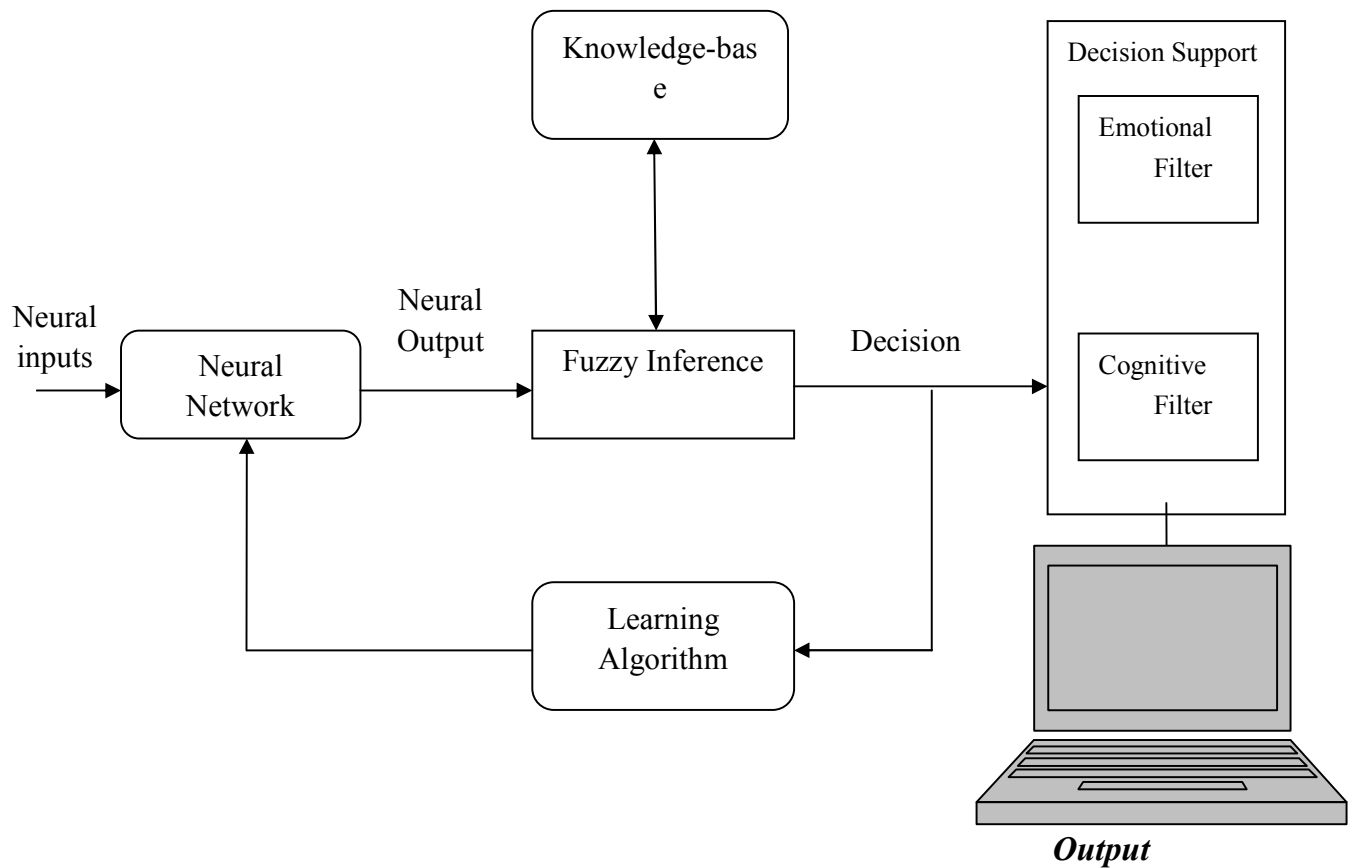
Figure 3: *Neuro-fuzzy Expert System for the Detection of Hypotension.*
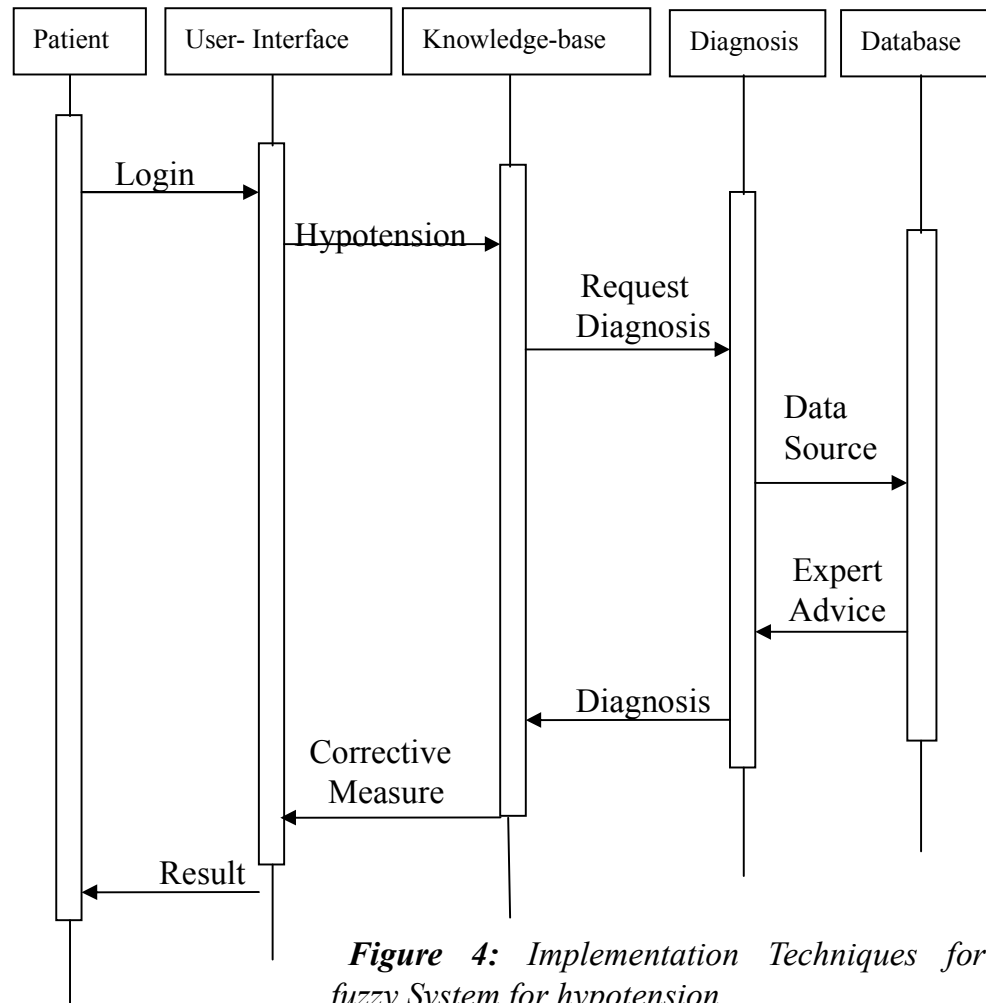
Figure 4: *Implementation Techniques for the Neuro-fuzzy System for hypotension*
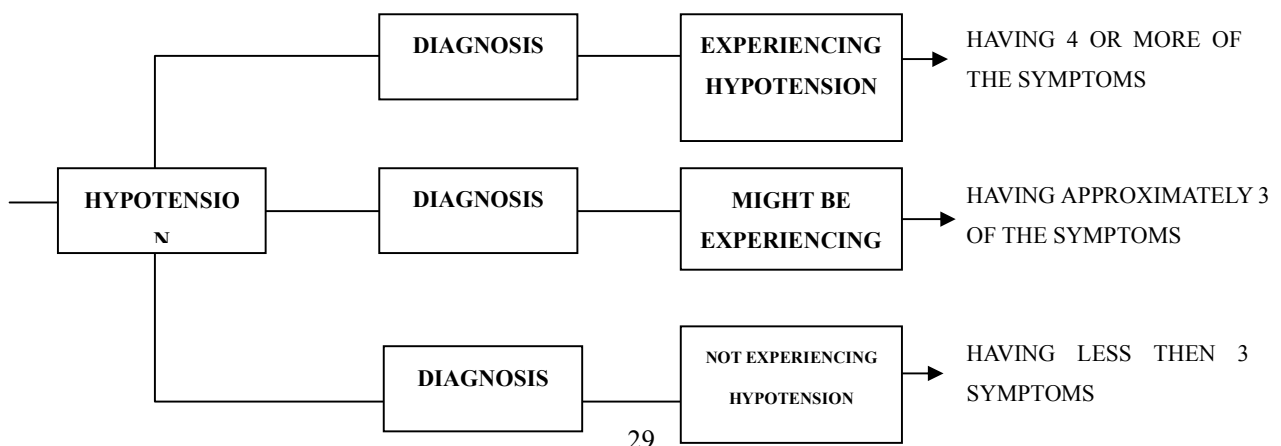
Figure 5: *Operational Procedure of the Neuro-Fuzzy System for the Diagnosis of Hypotension*
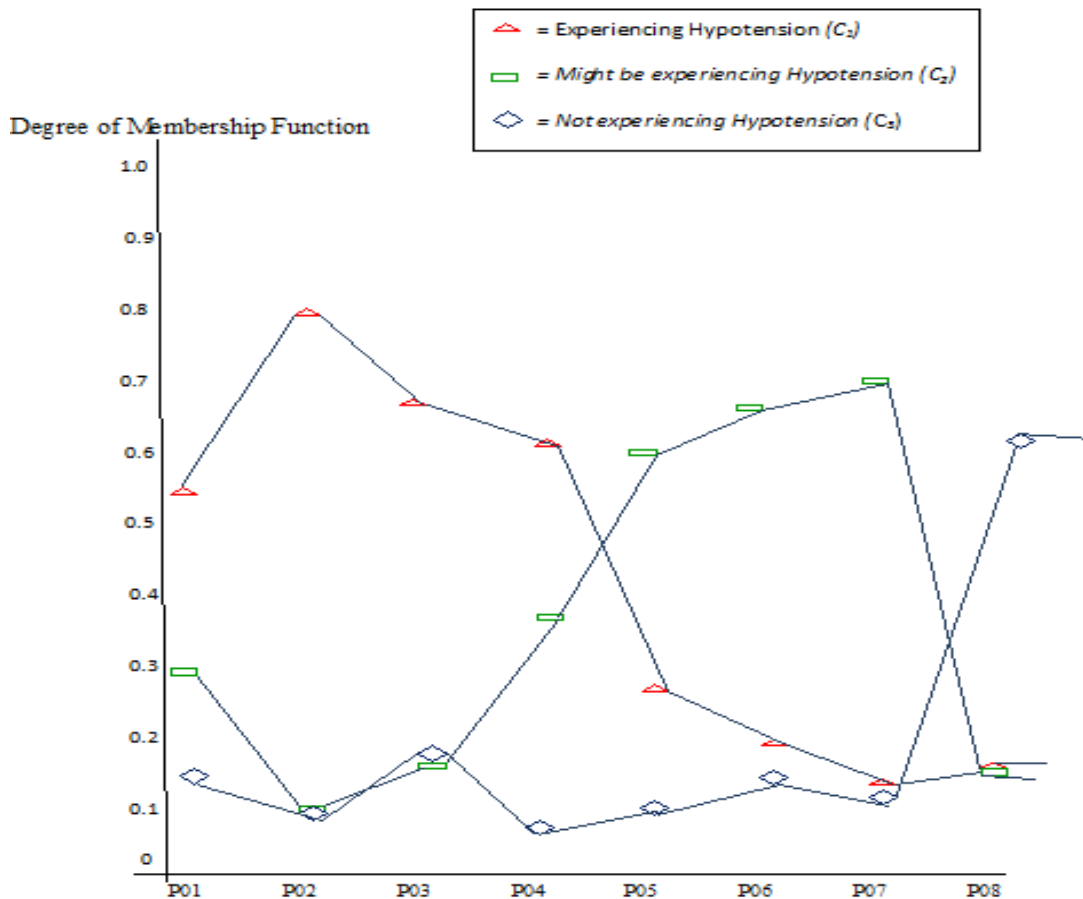
Figure 6: Graphical representation of Membership Grades of Hypotension clinical symptoms
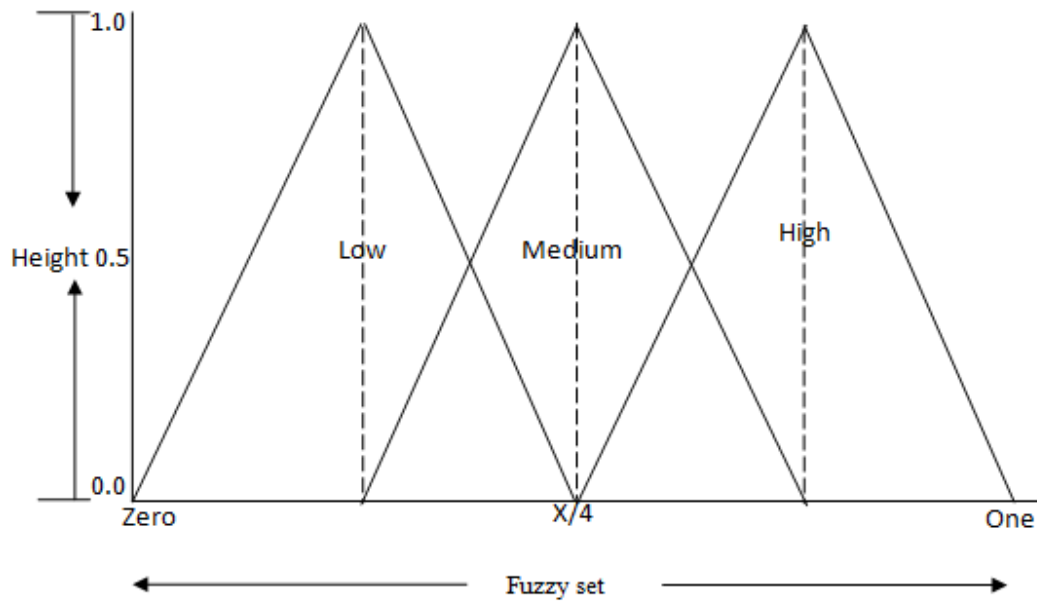
Figure 7: *Membership Function for Hypotension*