INTELLIGENT NEURO FUZZY EXPERT SYSTEM FOR AUTISM RECOGNITION

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ABSTRACT
Most children are not diagnosed with autism until they are around preschool age; the first signs of autism generally appear between 12 and 18 months of age. Autism is a brain disorder that is associated with a wide range of developmental problems (especially in communication, social interaction and unusual repetitive behavior). However, it is believed that at least some cases involve an inherited or acquired genetic defect. Researchers have proposed that the immune-system, metabolic, and environmental factors may play important part as well. A number of other possible causes have been suspected, but not proven. They involve, diet, digestive tract changes, mercury poisoning, the body's inability to properly use vitamins and minerals, vaccine sensitivity. The symptoms of autism includes: avoiding eye contact, play alone, not smiling, not responding to names, echolia (only parroting), unusual language, not talking, repetitive movement, self mutilation and reduced sensitivity to pain. 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 autism 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 autism.

Keywords: Neural Network, Fuzzy logic, Neuro Fuzzy System, Expert System, Autism

INTRODUCTION
Autism is a brain disorder that is associated with a wide range of developmental problems, especially in communication, social interaction and unusual and repetitive behavior. Some, but not all, people with autism are non-verbal (MedicineNet, 2011; WrongDiagnosis, 2011).

Some professionals use a broader term, called Pervasive Development Disorder (PDD), to describe autism. In addition to autism, there are four other disorders that qualify as PDD (WrongDiagnosis, 2011):

a. Asperger's syndrome (Asperger syndrome is a pervasive developmental disorder that is characterized by an inability to understand how to interact socially. Typical features of the syndrome also may include clumsy and uncoordinated motor movements, social impairment with extreme egocentricity, limited interests and unusual preoccupations, repetitive routines or rituals, speech and language peculiarities, and non-verbal communication problems).
b. Childhood disintegrative disorder
c. Pervasive Developmental Disorder-Not otherwise specified (PDD-NOS)
d. Rett syndrome (Rett syndrome is a disorder of the nervous system that leads to developmental reversals, especially in the areas of expressive language and hand use).

Most children are not diagnosed with autism until they are around preschool age the first signs of autism generally appear between 12 and 18 months of age (MedicineNet, 2011; WrongDiagnosis, 2011). The cause (or causes) of autism are not yet fully understood. However, it is believed that at least some cases involve an inherited or acquired genetic defect. Researchers have proposed that the immune-system, metabolic, and environmental factors may play an important part as well. A number of other possible causes have been suspected, but not proven. They involve, diet, digestive tract changes, mercury poisoning, the body's inability to properly use vitamins and minerals and vaccine sensitivity (Healthline, 2011; MedicineNet, 2011).

It is not caused by emotional trauma, as was once theorized.

The optimal treatment of autism involves an educational program that is suited to the child's developmental level. Diagnostic testing and evaluation of autism include routine developmental examinations done by pediatrician. Further testing may be needed if the doctor or parents are concerned. This is particularly true if a child fails to meet any of the following language milestones (Healthline, 2011; MedicineNet, 2011):

a. Babbling by 12 months.
b. Gesturing (pointing, waving bye-bye) by 12 months.
c. Saying single words by 16 months.
d. Saying two word spontaneous phrases by 24 months (Not just echoing).
e. Losing any language or social skills at any age.

These children might receive a hearing evaluation, blood lead test, and screening test for autism (such as the Checklist for Autism in Toddlers [CHAT] or the Autism Screening Questionnaire). A health care provider experienced in diagnosing and treating autism is usually needed to make the actual diagnosis. An evaluation of autism will often include a complete physical and nervous system (neurologic) examination. It may also include a specific screening tool, such as: Autism Diagnostic Interview - Revised (ADI-R), Autism Diagnostic Observation Schedule (ADOS), Childhood Autism Rating Scale (CARS) Gilliam Autism Rating Scale (GARS), and Pervasive Developmental Disorders Screening Test - Stage 3 (Healthline, 2011).

Children with known or suspected autism will often have genetic testing (looking for chromosome abnormalities) and may have metabolic testing (Healthline, 2011).

Autism includes a broad spectrum of symptoms. Therefore, a single, brief evaluation cannot predict a child's true abilities. Ideally, a team of different specialists will evaluate the child. They might evaluate: Communication, Language Motor skills, Speech, Success at school and thinking abilities (Healthline, 2011).

The symptoms of autism includes: avoid eye contact, play alone, not smiling, not responding to names, echolia, unusual language, not talking, repetitive movement, self mutilation and reduced sensitivity to pain.

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 for the diagnosis of autism will provide a self-learning intelligent system that is capable of handling uncertainties in the diagnostic process.

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 the other functions (Gary and George, 2002).

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

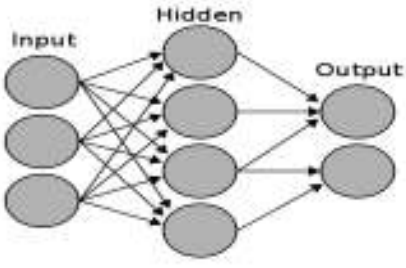


***Fig. 1**: A simple Neural Network*

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 (Dase and Pawar, 2010; Hiroshi *et al.,* 2011; Adyles and Fabrício, 2010; Valid and Gholam, 2009; 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 1) with tolerance interval [a, b], left width α and right width β if its membership function has the following form

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

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

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

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

Figure 1: *Trapezoidal fuzzy 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 (Jionghua et al, 2010; Saman, 2010; Stathacopoulou et al., 2004). Neu-

ro-fuzzy system for the diagnosis of autism disease will provide a self-learning and adaptive system that is able to handle uncertain and imprecise data.

METHODOLOGY

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

Neuro-fuzzy inference procedure is applied to the diagnosis of autism 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.

RESULTS AND DISCUSSION

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

a. Avoid eye contact
b. Play alone
c. Not smiling
d. Not responding to names.
e. Echolia
f. Unusual language
g. Not
h. Repetitive movement
i. Self-mutilation
j. Reduced sensitivity to pain

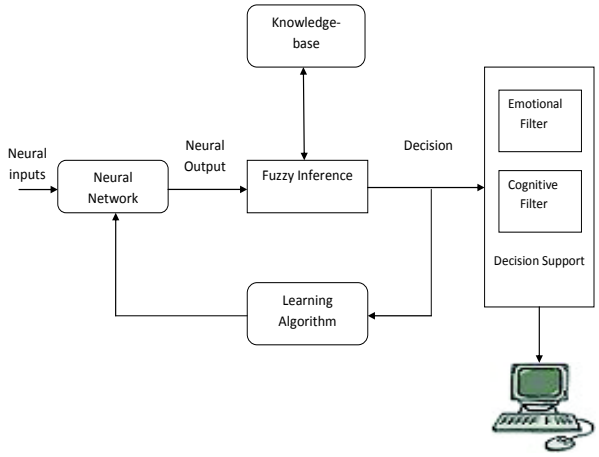


Fig. 3: *Neuro-fuzzy Expert System for the Diagnosis of Autism.*

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 j^{th} parameter and n is the number of parameter (in this case n=10). The set of linguistic values which is modeled as a linker scale denoted by 'L' is given as

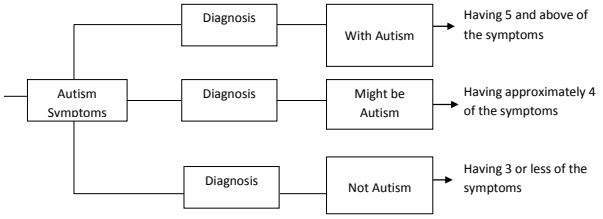
L= {Low, Moderate and High}.

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; 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 autism. 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 autism.

A universal set of symptoms of autism 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 Autism

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

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

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

SYMPTOMS	DEGREE OF INTENSITY OF AUTISM		
Avoid eye contact	0.60	0.30	0.10
Play alone	0.55	0.30	0.15
Not smiling	0.80	0.10	0.10
Not responding to names	0.68	0.15	0.17
Echolia (only parroting what they)	0.60	0.32	0.08
Unusual language	0.29	0.59	0.12
Not talking	0.20	0.65	0.15
Repetitive movement	0.18	0.70	0.12
Self mutilation	0.00	0.50	0.50
Reduced sensitivity to pain	0.20	0.20	0.60
RESULT	**With Autism**	**Might be Autism**	**Not Autism**

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 Autism"). When the fuzzy set is in-between zero and one, the condition is moderate ("might be suffering from Autism") and when it is between X/4 and one, the person's condition is high ("suffering from severe Autism").

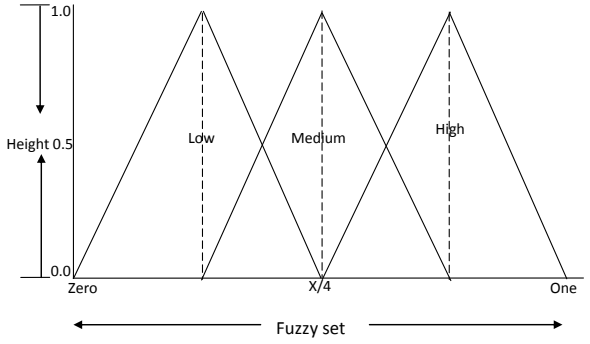


Figure 5: *Membership Function for Autism*

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 autism is represented in Figure 6.

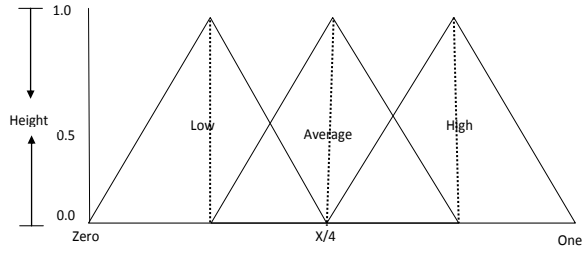


Figure 6: *Analysis of Autism Symptoms*

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 autism but, other kind of illness and diseases.

CONCLUSION

The need to design a system that would assist physician in medical diagnosis of autism 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 autism 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 autism. It should however be noted that the system was not designed to give prescription of autism 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 autism should be introduced in health care delivery centers and hospitals to help ease the work of physicians.

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