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FORMAL SPECIFICATION OF NEURO-FUZZY SYSTEM FOR OPTIMIZING HOSPITAL DISTANCE

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Abstract

Hospital Distance optimization using a hybrid formal method combined with neuro-fuzzy, bring in precision, in conjunction with self-learning ability and fuzziness elimination. Formal specification uses mathematical notation to specify clearly and unambiguously the properties a safety software system should possess. It focuses on "What" and not "How". This research paper attempts to define the properties a neuro-fuzzy system for hospital optimization will possess utilizing Zed notation in specifying these properties wherein interaction within the system was visualized using Unified Modeling Language (UML) sequence diagrams. The findings are: system failures are eliminated to a large extent while time usage invested in ratifying unknown errors will be saved. This research paper has provided a sample representation of formal specification.

Keywords: *Formal Specification, MATLAB Schema, UML, Z-Notation*

1.0 INTRODUCTION

River State, Nigeria is a commercial, multi-culture and age range city, with population density (persons with various attributes; age person, younger person and nursing mothers etc.) on the steady increase resulting in increased road creation, industries, residential estates as well creating chaotic and hectic traffic jam (CAPD, 2014). The health of every individual is of paramount importance to himself and the country of origin. It is important that securities of lives are guaranteed through quick response to health issues when they occur. The conventional approach adopted for distance optimization to a given health or medical center and hospital from a given community within Rivers State has been subjective at best; depending on the will, emotional state and experiences of an individual expert prescribing such information utilizing his/her head knowledge (Osami, 2013). There continuous and rapid optimization are totally impossible. This approach though useful in the age of no computer or computational devices has proving obsolete with the passage of time where most, if not all human endeavors are based on computer approaches. The loss of life, or even irreplaceable damages incurred by a patient due to poor distance prescription (delay time) to a given hospital has indeed been enormous within Rivers State.

This research paper formal define the precision a neuro-fuzzy system will possess utilizing Z-notation as the tool for formal method.

2.0 REVIEW OF RELATED LITERATURES

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"

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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).

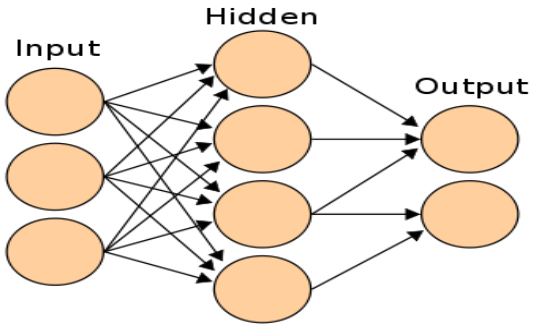

***Figure 1**: A simple Neural Network (*Leondes, 2010*)*

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

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

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 $(a - \alpha,\ b + \beta)$.

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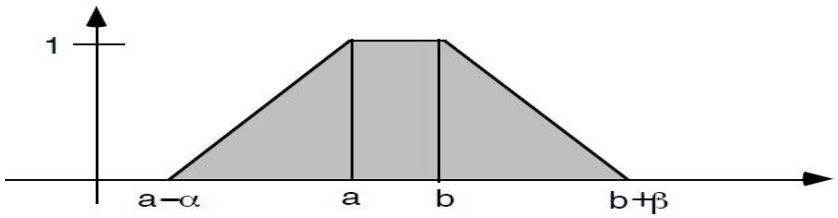

Figure 2: *Trapezoidal fuzzy number (*Leondes, 2010).

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 hypotension will provide a self-learning and adaptive system that is able to handle uncertain and imprecise data.

Z-notation uses mathematical notation to describe in a precise way the properties a software system must possess, without unduly constraining the way in which these properties are achieved (Spivey 1998, Sannella, 1998 and Spivey, 1992). Formal specification (Mathematical notation or Z) uses mathematical data types to model data in a system and achieve it underlining objectives. These data types are not oriented towards computer representation, but they obey a rich collection of mathematical laws which make it possible to reason effectively about the way a specified system will behave. We use the notation of *predicate logic* to describe abstractly the effect of each operation of our system, again in a way that enables us to reason about their behavior.

The other main ingredient in Z is a way of decomposing a specification into small pieces called *Schemas*. By splitting the specification into schemas, we can present it piece by piece. Each piece can be linked with a commentary which explains informally the significance of the formal mathematics. In Z, schemas are used to describe both static and dynamic aspects of a system (Spivey 1998). The static aspects includes

a. the state it can occupy;
b. the invariant (quantity that is unchanged by a set of mathematical operation) relationship that are maintained as the system moves from states to state.

The dynamic aspect Includes:

a. the operation aspect that are possible;
b. the relationship between their input and outputs;
c. the changes of state that happen.

The schema presented in this presented paper provided an avenue wherein our formal specification could be presented in fragment enabling us to

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associate commentary; explain informal the significance of the formal mathematical notation representation.

3.0 METHODOLOGY AND DESIGN

The methodology of this research focuses on proposing a Neuro-Fuzzy model and formalizing this method with Z-notation capable of optimizing shortest route to hospital locations and specifying the system properties formally. The model is depicted on Figure 2.

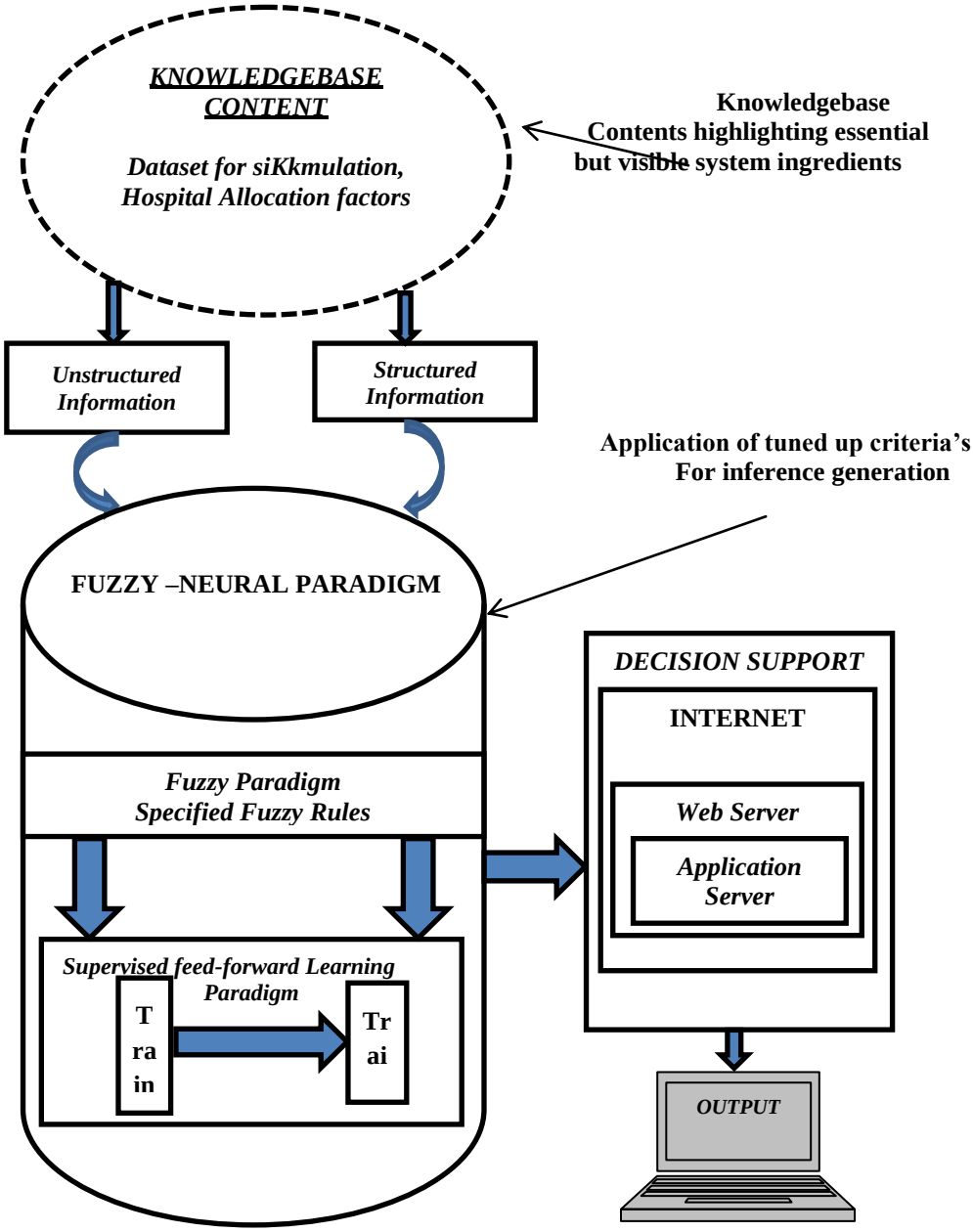

Figure 2*: Neuro- Fuzzy Model for Hospital Optimization*

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The model is composed of a front-end, web server, application server and backend engine. The front-end is the interactive web-based application running on the system, which provides an interface between the user and the computer system hardware and the system database. The web server helps to deliver web contents that can be accessed through the Internet. The web server in our framework delivers web contents on request to clients using the Hypertext Transfer Protocol (HTTP). The application server which runs inside our web server provides software applications with services such as security, data services, transaction support, load balancing, and management of large distributed systems. The backend database provides the central repository where information is stored and is retrieved through the database.

3.1 Formalization

The following are some of the basic types in Z {CHAR, STRING, CURRENCY, QUERY, OBJECT, COMPONENTS, BOOLEAN:: = TRUE/FALSE, DATA and OBJECT}. The format for Z schema is given in Figure 3.5

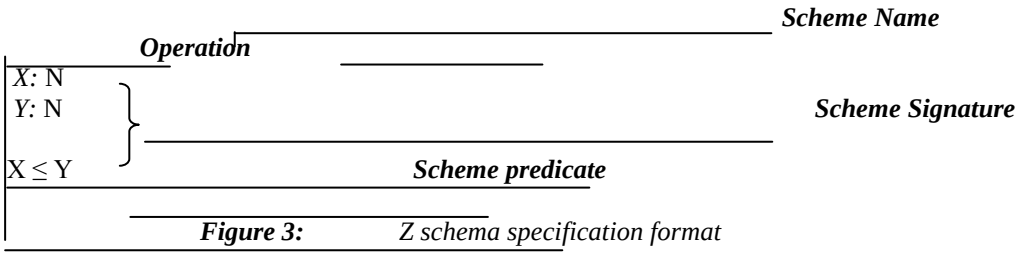

Figure 3: *Z schema specification format*

Formal specification for our system utilizing Z notation language will be annotated with clear and understandable commentary to assist the system designer, improve its understanding as shown in Figure 3.

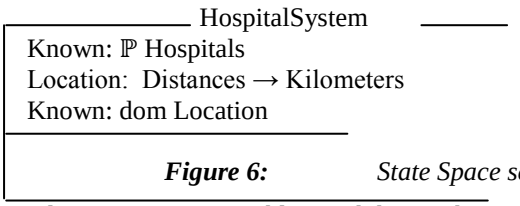

Figure 6: *State Space schema*

Known and Locations are variables, with known being the set of Hospitals location tied to Rivers State and Location is a function which, when applied to certain distances, gives the location associated with them which is clearly shown in figure 6.

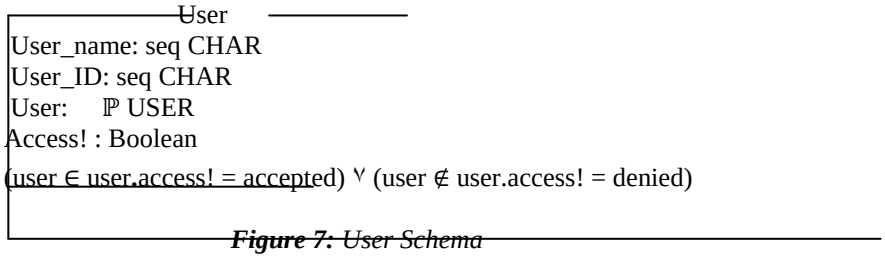

Figure 7: *User Schema*

Every User is authenticated using his username and ID. There is no frontier to the number of registered users and each user can have only one hospital location at a time. Logging on, each patient must enter its user ID with the Hospitals Directory which is clearly shown in Figure 7.

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Hospital Directory

Hospitals: ℙ Hospitals
Location: ℙ Locations
Directory: Hospital → Locations

Location = dom directory

Figure 8: *Hospitals Directory Schema*

The directory lists hospital within Rivers state and Location available on the directory which is clearly shown in figure 8

Recognize

Ξ HospitalDirectory
Location: LOCATIONS
Hospitalist? ℙ HOSPITALS

(Hospitallist! = {locations: locations/ directory (locations) =
Recognized?}∨ (locations ∉ locations ∧ report! = not_known)

Figure 9: *Recognize Schema*

The location function receives a request as an argument and returns the hospital particular to the request which is clearly shown in Figure 9.
The directory is initialized at the beginning with no hospital's record and no known location in Figure 10.

Initialize_Directory

Hospital Directory
Hospitals: ℙ HOSPITAL
Location: ℙ LOCATION
Hospital = ∅

Location = ∅

Fig 10: *Initialize_Directory Schema*

3.2 System Design and Unified Modeling Language (UML)

Software design immediately follows the requirements engineering phase in a software process. Software design is the translation of the requirement specification into useful patterns for implementation. Unified Modeling Language (UML) is a standard modeling language used for modeling software systems. We use UML for design of the system process because UML focuses on creating simple, well documented and easy to understand software models. UML sequence diagram shows the interaction between classes (or object) in the system for each use case. The interaction represents the order of messages that are exchanged between classes to accomplish a purpose. For the system we specify the properties utilizing sequence diagram specified on Figure 11.

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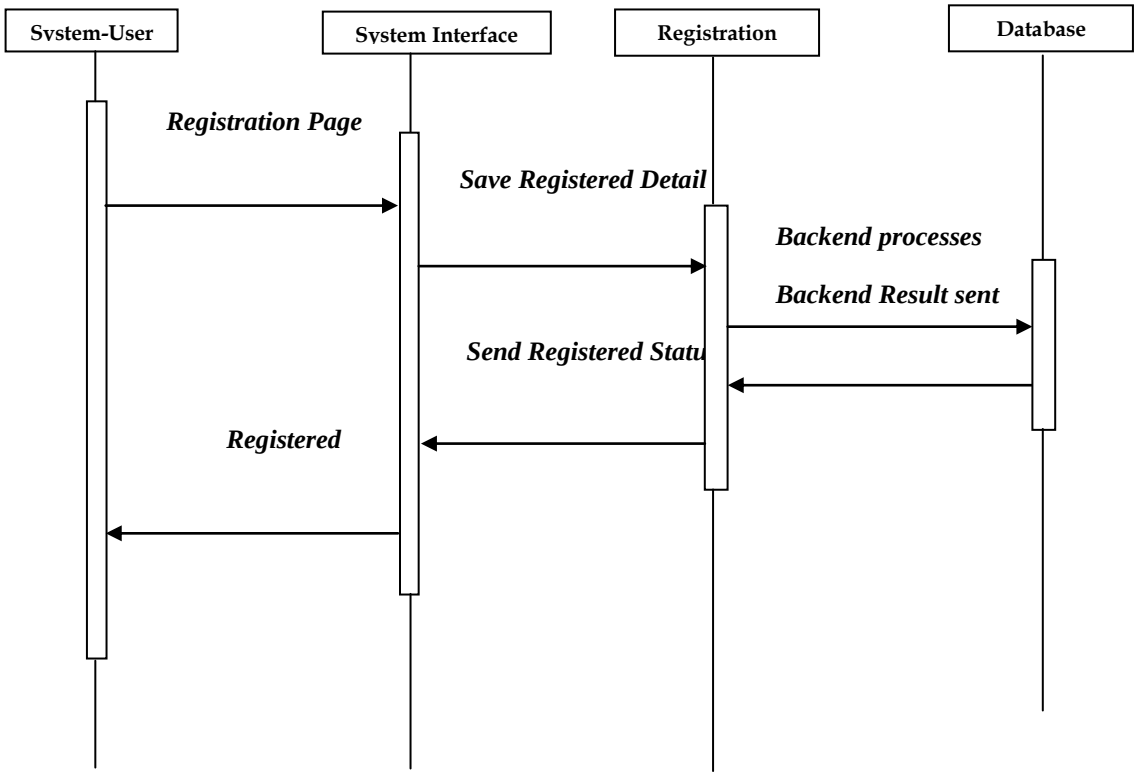

Figure 11: *Sequence Diagram modeling Registration Process*

3.3 Implementation

The implementation of the system was handled utilizing MATLAB, for several reasons:

a. It also manipulation across varied numerical data and
b. It integrates with numerous user interfaces.
c. Since formal specification are specified utilizing mathematical notation, MATLAB was at the frontier of all available implementation tools available to us due to it available mathematical ingredients.
d. It open source
e. Most importantly, it has a large active community base

Utilizing several MatLab tools such:

a. ***Assignment Statements***: Assignment statement as a MATLAB tool was used in overriding

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Predecessor variable while the successor variable took over. The assignment statement were used in the system to override previous entries which have be saved to the system database

b. ***Case Sensitivity:*** The variable name within are system were case sensitive acceding to Matric laboratory rules. The case sensitive rules in MatLab helped us in distinctively separating our variables name

c. ***Immediate and Deferred Execution****:* When MATLAB is invoked; the user is presented with an *interactive environment*. Enter a statement, press the carriage return ("ENTER") and the statement is immediately executed. Given the power that can be packed into one MATLAB statement, this is no small accomplishment.

4.0 FINDINGS

Based on the ease at which the users retrieve relevant hospital distance information through this new system, the following are revealed:

a. Ambiguity in system properties has been reduced to a minimum

b. Save time otherwise investigated in ratifying unknown errors

5.0 CONCLUSION.

Formal specification is the bedrock of safety critical system which uncovers ambiguities and unwanted error from system requirement. In most system built in Nigeria, implementation of system formal specification has been shoved aside. This research paper focuses on specifying a neuro-fuzzy system back-up by formal specification. The system design was specified utilizing UML while implementation was handled exploring MATLAB. The results of the finding were listed assiduously.

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