

# Fuzzy Expert System for the Management of Hypertension.

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## ABSTRACT

This paper focused on the use of information and communication technology (ICT) to design a web-based fuzzy expert system for the management of hypertension using the fuzzy logic approach. In this paper, systolic blood pressure, diastolic blood pressure, age, and body mass index (BMI) were taken as input parameters to the fuzzy expert system and "hypertension risk" was the output parameter. The resultant hypertension risk was based on fuzzy rules that were developed for the expert system. The input triangular membership functions are Low, Normal, High, and Very High for blood pressure. The output triangular membership functions are mild, moderate and severe. The defuzzification method used in this paper is the Root Sum Square. The expert system was designed based on clinical observations, medical diagnosis, and the experts' knowledge. The expert system provides a web-based interface that was designed using PHP as a scripting language with MySQL relational database on Apache Server under Windows operating system platform, and using Java Script and HTML to archive the system design. Unified Modeling Language was used to describe the logical design of the system. We selected 50 patients with hypertension and computed the results that were in the range of predefined limit by the domain experts.

(Keywords: fuzzification, defuzzification, fuzzy logic, fuzzy expert system, membership function, rule base, hypertension risk, systolic blood pressure, SBP, diastolic blood pressure, DBP, body mass index, BMI, web based tools)

## INTRODUCTION

The emergence of information technology (IT) has opened unprecedented opportunities in

health care delivery system as the demand for intelligent and knowledge-based systems have increased as modern medical practices become more knowledge-intensive. The developed and the developing world currently face a series of health crises including hypertension management that threaten the lives of millions of people. There is a constant drive to improve the management of hypertension by the Health Care Delivery Sector. Information and Communication Technology (ICT) as an agent of change has affected all aspects of the society including medical practices.

The applicability of IT in medical practice dates back to the 1950's in USA when the computer was first used to stored patient data. In this dynamic world, IT seeks to bridge the existing gap between traditional healthcare delivery and modernized healthcare delivery; as a result the scientific basis of medicine is constantly changing.

The diagnosis of hypertension involves several levels of uncertainty and imprecision. The task of hypertension diagnosis and management is complex because of the numerous variables involved. It is made more so because of a lot of imprecision and uncertainties. Patients cannot describe exactly how they feel; doctors and nurses cannot tell exactly what they observe; and laboratories results are dotted with some errors caused either by the carelessness of technicians or malfunctioning of the instruments.

Medical researchers cannot precisely characterize how diseases alter the normal functioning of the body (Szolvits, 1988). Hypertension can become so complex and unpredictable that physicians sometimes must make decisions based on intuition. All of these complexities in medical practice make traditional quantitative approaches of analysis

inappropriate. Fuzzy logic plays an important role in medicine. Fuzzy logic is a method that renders precise what is imprecise in the world of medicine using natural language. Fuzzy logic systems are excellent in handling ambiguous and imprecise information prevalent in medical diagnosis. Fuzzy set and fuzzy logic founded by (Zadeh, 1965) makes it possible to define inexact medical entities as fuzzy set.

Theory of fuzzy sets and fuzzy logic is efficient method for treating the uncertain and imprecise data of any kind. It has such characteristics that enable researchers to provide the high rationality when modeling the uncertain, incomplete and fuzzy data that exist in clinical practice. The basic aim of the fuzzy sets theory and fuzzy logic is exploitation of the tolerance that exists in imprecise, vague or partially truth data for obtaining the more robust and cheaper solutions (Zimmermann, 1987a). The main advantage of the fuzzy approach to modeling of uncertainties, comparing to other techniques and methods of the Artificial Intelligent is that, the expert knowledge is represented in the form of natural language which is the most suitable for communication as it was improved and optimized for centuries (Odejebi, 1997). From the point of view of mathematics, expert knowledge is represented by the linguistic variable, which is quantitatively described in the theory of fuzzy sets (Zimmermann, 1996b). Hence fuzzy logic is a qualitative computational approach that was used in this paper.

Fuzzy logic is one of the methods of Soft Computing. Soft Computing is a computational method that is tolerant to sub-optimality, impreciseness, vagueness and thus giving quick, simple and sufficient good solutions (Chen and Chen, 1994). Most of the cardiac diseases are characterized by varied degrees of intricacy and the conventional procedures are not capable of dealing with these intricacies very efficiently (Nalayini and Wahida, 2008).

Hypertension is one of the known cardiac diseases believed to be the cause of the "sudden death" syndrome prevalent in Nigeria today (Ogah, 2006). Complications of hypertension could lead to stroke or heart failure (Hobbs and Boyles, 2004). Such complications may be caused by improper diagnosis and or improper management of the disease, due to inaccessibility of experienced medical personnel at all times. This necessitated the dire need for a

tool that is readily available to render up-to-date medical information to the patient.

### **Fuzzy Logic and Hypertension**

The complexity of medical practices makes traditional quantitative approaches of analysis inappropriate (Rahim et al., 2007). Every trust worthy expert knows that his/her medical knowledge and resulting diagnosis are pervaded by uncertainty with imprecise formulations. Medical processes can be so complex and unpredictable that physicians sometimes must make decisions based on intuition. Computers are capable of making calculations at high and constant speed and of recalling large amounts of data and can, therefore, be used to manage decision networks of high complexity (Merouani et al., 2009).

Fuzzy logic developed by Zadeh (1965), makes it possible to define these inexact medical entities as fuzzy sets. Fuzzy logic together with the appropriate rules of inference provides a power framework for managing uncertainties pervaded in medical diagnosis (Ludmala and Steimann, 2008). Fuzzy logic technology is adopted in this paper for the management of hypertension. This is because, fuzzy logic can adequately address the issue of uncertainty and lexical imprecision of knowledge (Akinyokun and Adeniji, 1991) and (Fuller and Giove, 1994), but fuzzy systems still requires human expert to discover rules about data relationship.

By applying fuzzy logic, fuzzy rule base system for the management hypertension was developed by the domain expert.

### **PATIENTS AND METHODS**

We selected 50 patients with hypertension, aged between 20 and 70 years and weight between 45 and 90 kg. In this sequel, we made an honest attempt to incorporate fuzzy approach and developed a web-based fuzzy expert system for the management of hypertension. In order not to leave the system design incomplete, for logical modeling, Unified Modeling Language (UML) was used in order to achieve a concise and systematic modeling. For physical modeling, the system was developed using PHP as a scripting language with MySQL relational database on Apache Sever under windows

operating system platform, Java Script, and HTML to archive the system design.

### **Logical System Modeling**

UML, as an object oriented tool, was used to capture and model some of the functionalities in the system. UML is an excellent tool for modeling objects and the relationship between the objects and classes. (Kendall and Kendall, 2002). The UML approach helps to depict the system in many different views thus giving a quick structural representation of the system.

There are two types of UML diagrams: the structural diagram and the behavioral diagram. Structural diagrams are used to describe the relationship between classes. They include class diagrams, object diagram, use-case diagrams, component diagrams, and deployment diagrams. Behavioral diagrams on the other hand can be used to describe the interaction between objects. They include sequence diagram, collaboration diagrams, state chart and activity diagram (Alhir, 2000). In this paper, we made use of three UML diagrams: use-case diagram, sequence diagram and class diagram. The use-case diagram is the description of the systems behavior from a user's point of view. This diagram is a valuable tool during system analysis and design as developing use-cases help to understand system requirements. The use-case diagram is shown in Figure 1. The actors are the patient and the medical expert as they are the individuals that interact with the system.

The sequence diagram; a derivative of the use-case analysis illustrates the processing described in the use-case scenario. The sequence diagram describes how the objects in the system interact over time. The objects identified in the system are the patient, the user interface, knowledge-base, diagnosis and management, prescription and medical expert. The objects interact in the sequence shown in Figure 2 below by passing messages across the timeliness represented by arrows.

Class diagram is used to show generalization and composition association in our system. Classes usually inherit functionality from other classes. Similarly classes are contained in other classes. In the class diagrams below (Figure 3 and Figure 4), an arrow shows a generalization

(inheritance) while a filled diamond shows composition (containment) relationship

### **Physical System Design**

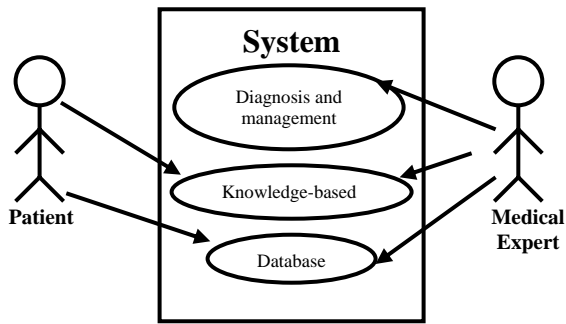
The system consists of three modules: the patient module, medical repository module and the fuzzy rule base module. The software modules are developed using using PHP as a scripting language with MySQL relational database on Apache Sever under windows operating system platform, Java Script and HTML to archive the system design. The basic data exchange between the software components and the patient is through web services. The message exchange has been implemented through Simple Object Access Protocol (SOAP). The medical expert and the patient can both call the knowledge-base. Appropriate graphical user interface (GUI) is developed that allows the doctor to enter/change/retrieve patient data (See Appendix). Another administrative GUI is designed in order to manage registered users who do not belong to a specific doctor. The patient or the registered user has access to his/her diagnosis but is not able to modify the data that was entered by the doctor or the system administrator (See Appendix for the physical modeling).

### **Database**

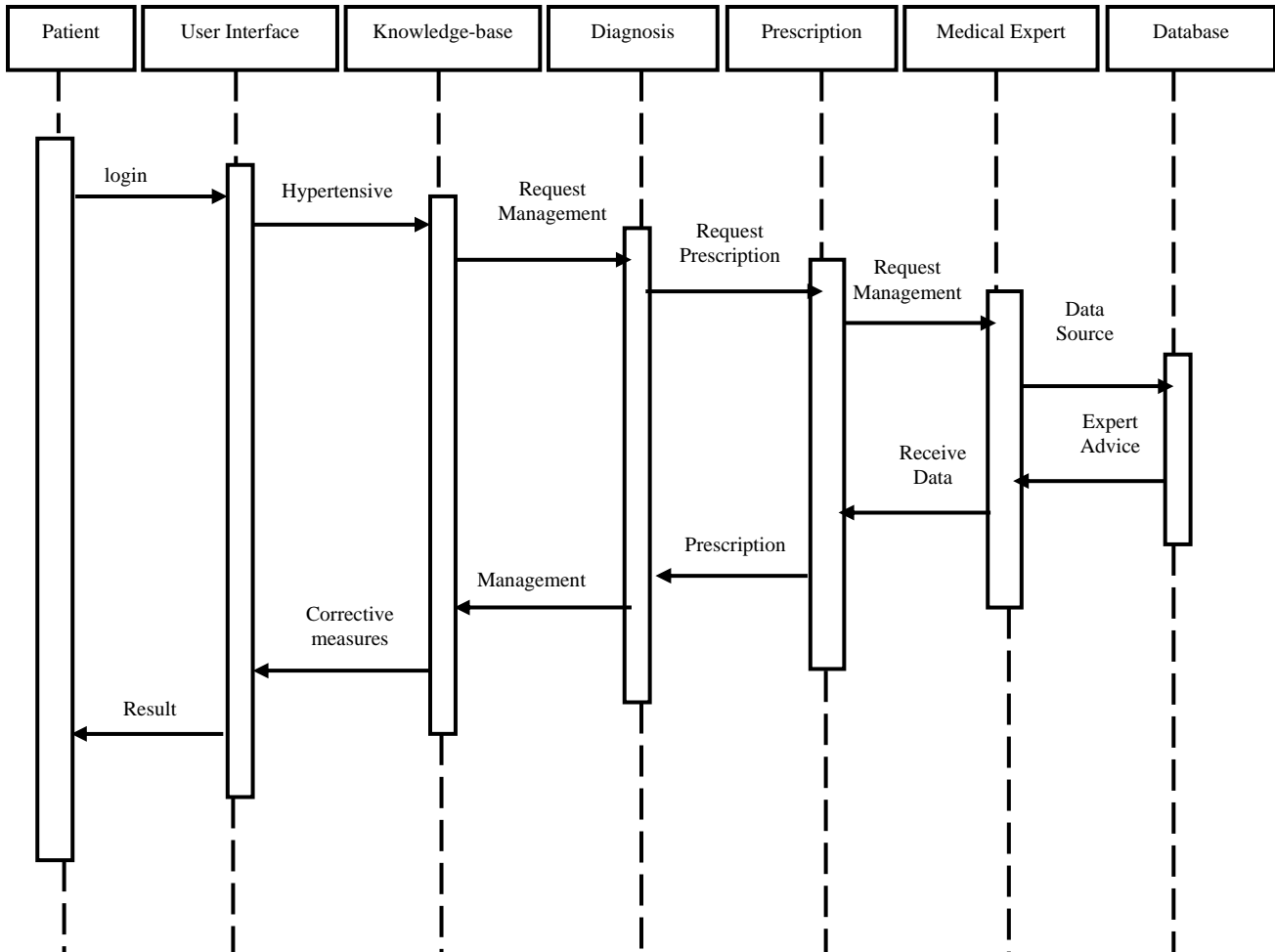
At the back-end, we utilize a database management system. This database holds all existing patient data, permits changes to that data and allows for addition of new patients and patient data. Also registered user data is stored in this database (users who do not have a doctor) so that these users also are able to obtain hypertension diagnosis from the system. Database is implemented by usage of MySQL technology.

### **Fuzzy Expert System**

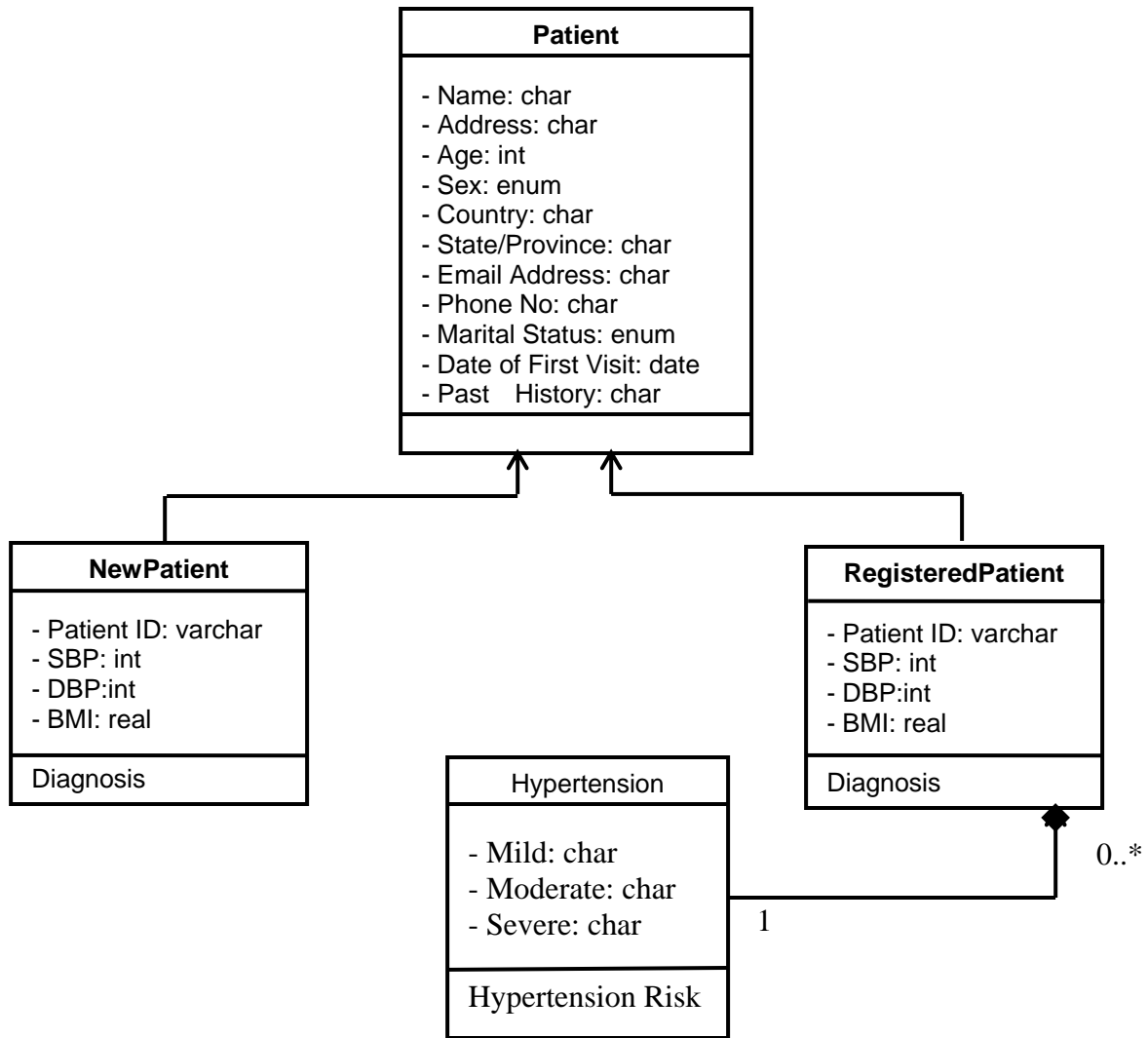
A fuzzy expert system is a form of artificial intelligence (computer hardware and software packages that try to emulate human intelligence, using reasoning and learning to solve problems) that uses a collection of membership functions (fuzzy logic) and rules to reason about data.



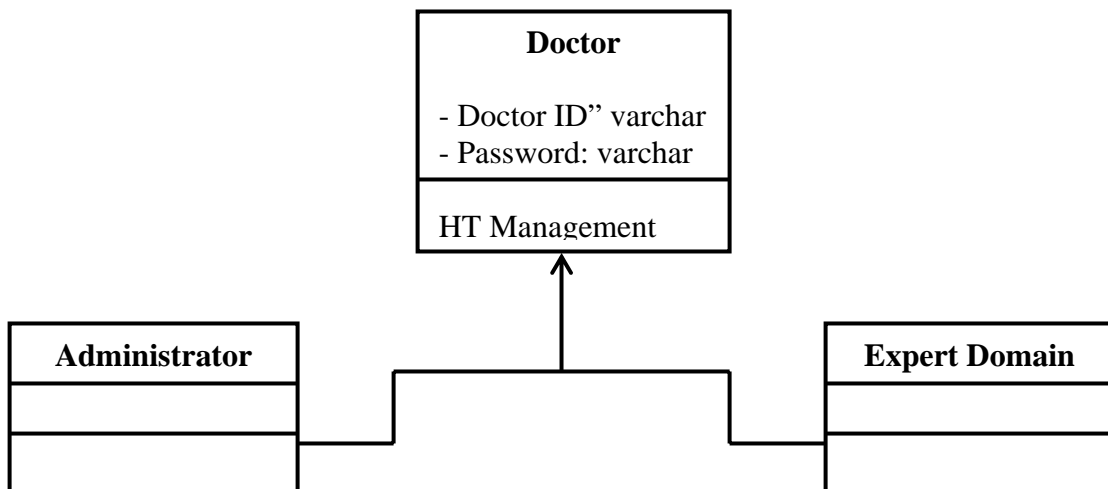
**Figure 1:** Use-Case Diagram for Patient and Doctor.



**Figure 2:** Sequence Diagram for the System.



**Figure 3:** Class Diagram Showing Attributes, Generalization, and Composition Association



**Figure 4:** Doctor Class Diagram.

Systolic blood pressure (SBP), diastolic blood pressure (DBP), age, and body mass index (BMI) are taken as input parameters to the fuzzy expert system and "hypertension risk" is the output parameter of the fuzzy expert system.

The linguistic variables mild, moderate and severe were used for SBP and DBP, the linguistic variables young, middle age, old, and very old for Age, and the linguistic variables low, normal high and very high for BMI.

The knowledge was elicited from the expert through interview and literature search. The knowledge was represented in the system using the rule-based approach. The fuzzy expert system underwent three transformational stages such as Fuzzification, Rulebase, and Defuzzification processes.

**Fuzzy Representation of Input and Output Parameters as Membership Function**

Fuzzification is a process that determines the degree of membership to the fuzzy set based on fuzzy membership function.

Analytical representation of membership function for the four input parameters to the fuzzy expert system is shown below:

$$SBP(i) = \begin{cases} i; & 80 \leq i \leq 300 \\ 0; & i < 80 \\ 1; & i > 300 \end{cases} \dots\dots\dots(1)$$

*i* represents several measurements of SBP

$$DBP(j) = \begin{cases} j; & 30 \leq j \leq 160 \\ 0; & j < 30 \\ 1; & i > 160 \end{cases} \dots\dots\dots(2)$$

*j* represents several measurements of DBP

$$Age(h) = \begin{cases} h; & 20 \leq h \leq 70 \\ 0; & h < 20 \\ 1; & h > 70 \end{cases} \dots\dots\dots(3)$$

where *h* represents patient's age

$$BMI(l) = \begin{cases} l; & 20 \leq l \leq 25 \\ 0; & l < 20 \\ 1; & l > 25 \end{cases} \dots\dots\dots(4)$$

where *l* represents patient's BMI

Graphical representation of membership function (blood pressure) is shown in Figure 5 below:

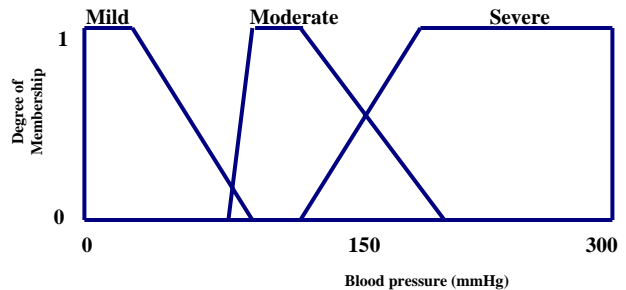


Figure 5: Membership Function for Blood Pressure.

**Fuzzy Rule Base**

The heart of a fuzzy logic expert system is the Rule Base. Rules are predefined and are evaluated by combining degrees of membership to form output strengths. The Rule Base consists of a set of Fuzzy Propositions and is derived from the Knowledge Base of the Medical Expert. A fuzzy proposition or a statement establishes a relationship between different input fuzzy sets and output sets. Fuzzy-logic offers a possibility to update the knowledge base continuously (Mihaela, 2003) and by this improves previous diagnosis. Sample rules from the proposed fuzzy expert system are show in Table 1.

After proposition (rules), the next phase is to perform defuzzification in order to evaluate the crisp output.

**Defuzzification**

The main objective of this study is to determine hypertension risk based on the linguistics description of the input parameters SBP, DBP, BMI, and age. Hypertension risk will be based on fuzzy rules, which have different antecedent parts but with the same consequence. The problem is that we have to work out a final numerical value with the fuzzy inputs. This can be achieved only with defuzzification process.

**Table 1:** Sample Rules for the Proposed Fuzzy Expert System.

Rule No	IF				THEN
	SBP	DBP	AGE	BMI	Hypertension Risk
1	Mild	Severe	Young	Low	Mild
2	Moderate	Moderate	Middle Age	Normal	Mild
3	Severe	Mild	Old	High	Moderate
4	severe	mild	Very Old	Very High	Moderate
5	Mild	Mild	Very Old	Normal	Mild
6	Moderate	Moderate	Old	Very High	Moderate
7	Mild	Severe	Middle Age	High	Severe
8	Moderate	mild	Young	Low	Severe
9	Severe	Mild	Middle Age	Low	Mild
10	moderate	Moderate	Young	Normal	Moderate
11	Mild	Severe	Old	High	Moderate
12	Mild	Severe	Very Old	Very High	Mild
13	Moderate	Moderate	Young	Low	Moderate
14	Severe	mild	Middle Age	Normal	Severe
15	severe	Mild	Old	Normal	Severe
16	moderate	Moderate	Very Old	Low	mild
17	Mild	Severe	Old	Normal	Mild
18	Mild	moderate	Young	High	Severe
19	severe	mild	Middle Age	Very High	Severe
20	moderate	Moderate	Very Old	Normal	mild

**Table 2:** Range of Fuzzy Values for Hypertension Risk.

Range of Fuzzy Values for Hypertension Risk	
0.1 - 0.4	Mild
0.41 - 0.61	Moderate
0.62 - 1.0	Severe

In sum, we deal with fuzzy input but the end product must be a crisp value. In this paper, we decided to use the Root Sum Square to get a crisp out.

Defuzzification refers to the reduction of a range of conclusions with different membership to a single point output. Defuzzification is determined using the method: **Root Sum Square (RSS)** as given by the formula below:

$$RSS = \sqrt{r^2} \dots\dots\dots(5)$$

**RESULTS**

Based on RSS, hypertension risk was computed for 50 patients' data. The example below shows sample values of 5 patient data:



**Table 3:** Sample Data Collected from 5 Patients.

S/N	SBP(mmHg)	DBP(mmHg)	BMI(kg/m2)	Age
1	70mmHg	60	35	28
2	78	30	30	55
3	68	110	41	36
4	90	47	30	57
5	66	80	47	65

The above data in Table 3 were fuzzified into the fuzzy value range by the domain expert as show in Table 4 below:

**Table 4:** Fuzzified Table of Patient Data.

S/N	SBP	DBP	BMI	Age
1	Mild 0.3	Mild 0.2	High 0.4	Young 0.3
2	Moderate 0.2	Mild 0.1	Normal 0.2	Middle age 0.1
3	Mild 0.1	Severe 0.3	High 0.5	Young 0.2
4	Moderate 0.3	Moderate 0.4	Normal 0.2	Middle age 0.3
5	Mild 0.1	Severe 0.9	Very high 0.4	Old 0.1

From the fuzzy rules predefined above and using RSS, hypertension risk can be computed as shown:

$$RSS = \sqrt{r^2}$$

$$RSS = \sqrt{(0.3)^2 + (0.2)^2 + (0.4)^2 + (0.3)^2}$$

$$= 0.61$$

Based on RSS, the computed value for hypertension risk for the first sample of patient data is 0.61. The crisp output of 0.61 show that the patient has moderate risk of hypertension; thus, the patient needs close monitoring and possible indication for treatment of hypertension. The results for RSS value, the crisp out and hypertension risk are shown in Table 5.

## CONCLUSION

On the basis of the all presented, it can be concluded that there is no doubt whether Expert Systems should be applied for hypertension management. Our results based on real patient data confirms that the fuzzy logic expert system can represent the expert's thinking in a satisfactory manner in handling complex trade-offs. Fuzzy logic systems are excellent in handling ambiguous and imprecise information prevalent in medical diagnosis.

**Table 5:** Results Showing RSS Value, the Crisp Output, and Hypertension Risk.

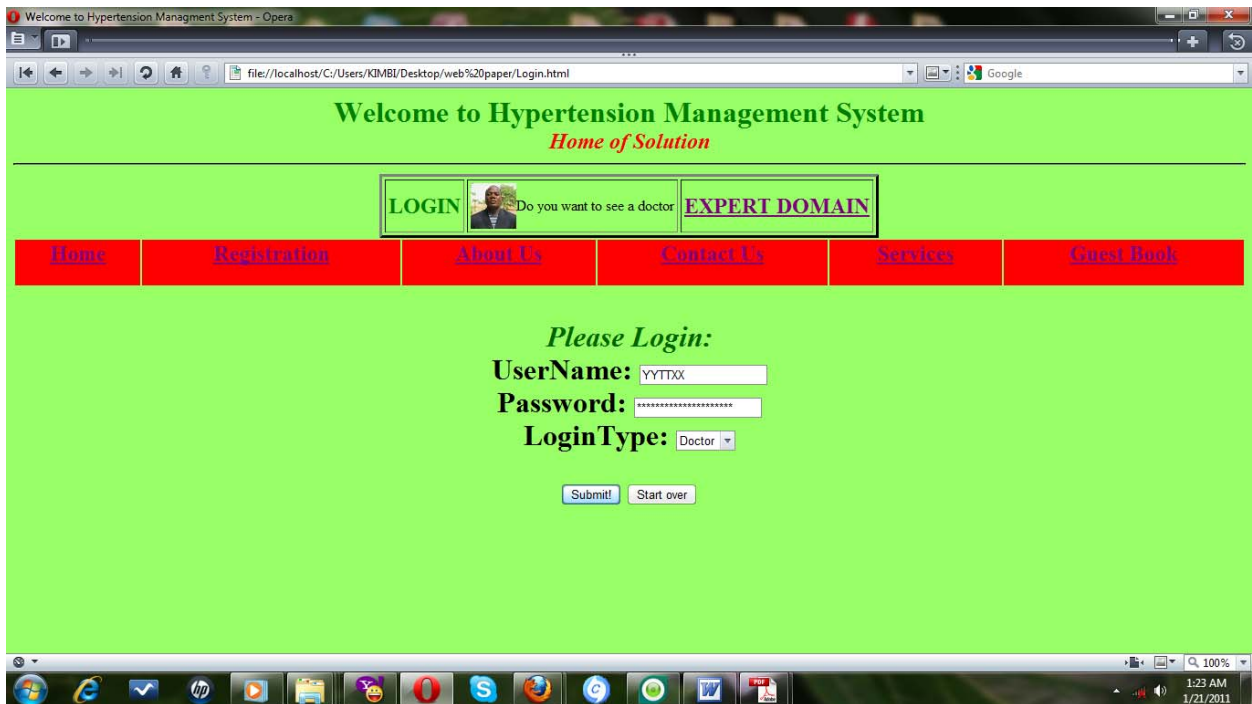
S/N	SBP	DBP	BMI	Age	Crisp Output	Hypertension risk
1	0.3	0.2	0.4	0.3	0.61	Moderate
2	0.2	0.1	0.2	0.1	0.31	Mild
3	0.1	0.3	0.5	0.2	0.62	Moderate
4	0.3	0.4	0.2	0.5	0.71	Severe
5	0.1	0.9	0.4	0.4	0.99	Severe



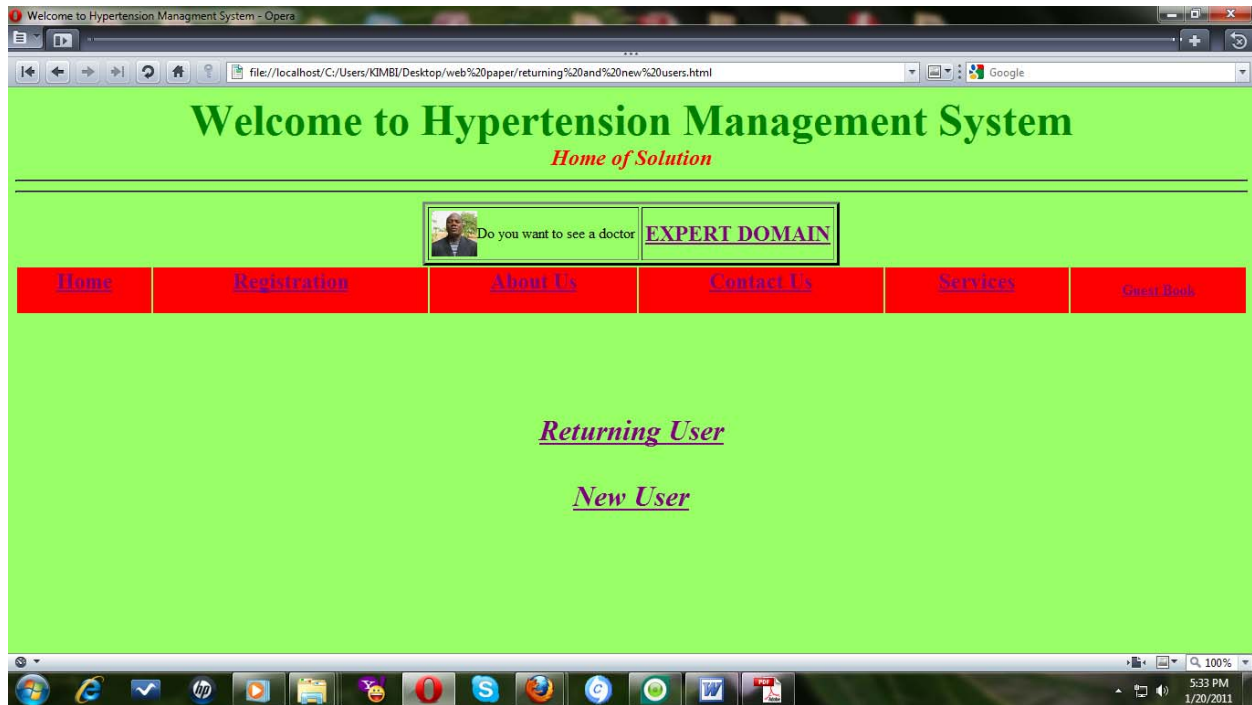
## APPENDIX



A-1: Homepage for the System.



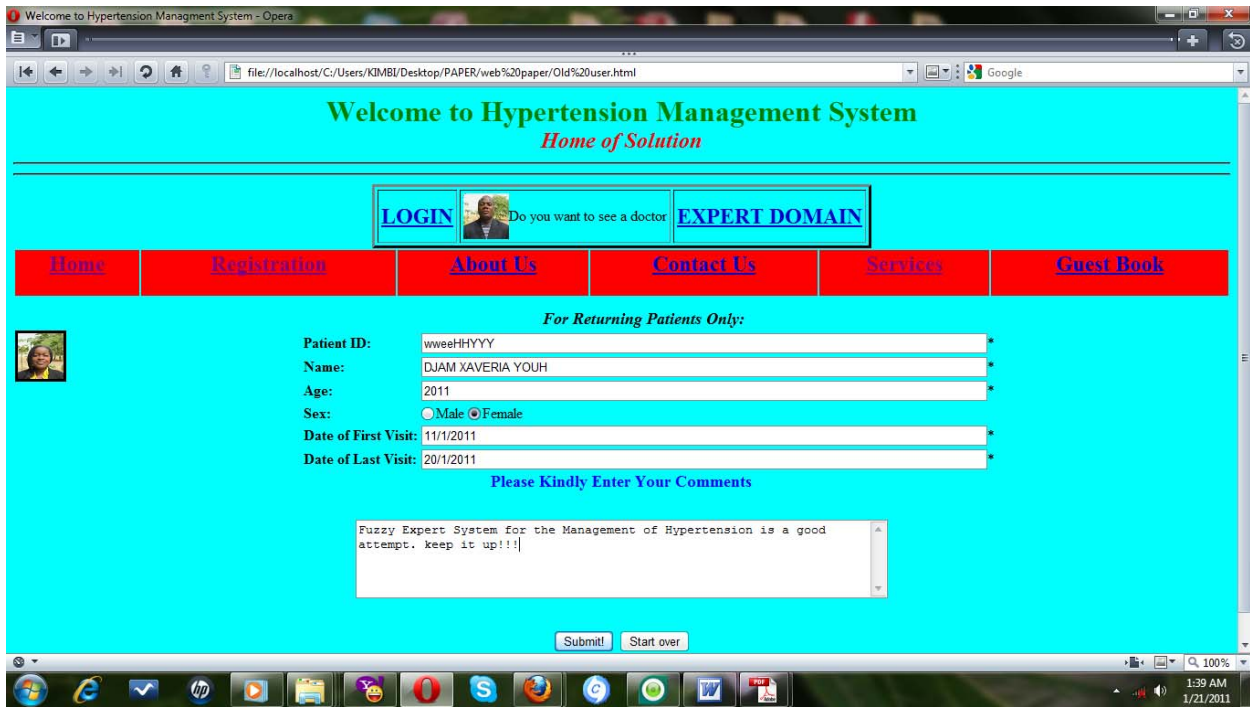
A-2: Login Web Page.



A-3: Web Page for Both Returning and New Users.



A-4: Registration Web page for New Patients.



A-5: Webpage for Registered Patients.



A-6: Web Page for Expert Domain.



A-7: Web Page about the Author.

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## SUGGESTED CITATION

Djam, X.Y. and Y.H. Kimbi. 2011. "Fuzzy Expert System for the Management of Hypertension". *Pacific Journal of Science and Technology*. 12(1): 390-402.



[Pacific Journal of Science and Technology](http://www.akamaiuniversity.us/PJST.htm)

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