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Fuzzy Expert Model for Diagnosis of Lassa Fever

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Abstract

Lassa fever is an epidemic hemorrhagic fever caused by the Lassa virus. This disease can be passed from animals to humans and from humans to humans. It is difficult to diagnose because most of its symptoms are non-specific to the disease.

This research work focused on information communication technology to design a web-based fuzzy expert system for diagnosis of Lassa Fever (LF) using fuzzy logic approach. In this study, Fever (F), Abdominal pain (AP), Proteinuria(P) and Thrombocytopenia (T). Where taken as input parameters to the fuzzy expert system and Lassa fever suspicion as output parameter. The presence of high grade fever, proteinuria and thrombocytopenia in patients with acute abdominal pain should heighten the suspicion of Lassa fever. A range was given to determine the suspicion level of the disease. The output membership functions are high suspicion of Lassa fever, suspicion of Lassa fever and no suspicion of Lassa fever. Unified modeling languages (UML) were adopted to model the structural and behavioral view of thesystem using use case diagram and sequence diagram.

Keywords: Fuzzy logic, fuzzification, defuzzification, Lassa Fever, Abdominal Pain(AP), Proteinuria(P)and Thrombocytopenia (T). Suspicion, Expert System.

1.0 Introduction

Lassa fever is an epidemic hemorrhagic fever caused by the Lassa virus, an extremely virulent arenavirus. As many as 100 cases occur annually in western Africa; the disease is rare in the United States. This highly fatal disorder kills 10% to 50% of its victims, but those who survive its early stages usually recover and acquire immunity to secondary attacks.

Lassa fever is a contagious disease that can be passed from animals to humans and from humans to humans. The virus that causes the disease is passed in the stool and urine of infected persons. It is difficult to diagnose because most of its symptoms are non- specific to the disease. However, it is characterized as a hemhorragic fever as it causes bleeding of the mucous membrane. It is characterized by fever, muscle aches, sore throat, nausea, vomiting, and chest and abdominal pain [1]. The virus exhibits persistent, asymptomatic infection, with profuse urinary virus excretion in *Mastomysnatalensi*s, the ubiquitous and highly commensal rodent host [2,3]. Early clinical manifestations are often indistinguishable from those of many other febrile illnesses, making clinical diagnosis difficult [4].

The high virulence and fatality rate of this disease is a major concern which is further complicated by the non-specific modes of presentation (mimicking some other fevers). From the foregoing, early presentation and subsequent diagnosis is usually not feasible. The contagious nature of the illness poses a big threat to the Medical attendants, other hospital workers and the caregivers who often are exposed to this disease unprotected, prior to diagnoses and establishment of barrier nursing. The fomite and aerosol mode of contraction posses a huge challenge to all who have close contact with the patients. The inherent danger of complications that survivors and sub-clinically exposed individuals might suffer from is a concern.

So computer assisted decision support system is needed to intelligently filter the right disease and to foster the better medication to the needy patients.

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[5]. Fuzzy logic developed by Zadeh [6], 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[7]. Fuzzy logic technology is adopted in this work for the diagnosis of Lassa fever. This is because, fuzzy logic can adequately address the issue of uncertainty and lexical imprecision of knowledge [8,9], but fuzzy systems still requires human expert to discover rules about data relationship. The application of fuzzy logic, fuzzy rule base system for the diagnosis of Lassa fever was developed by the domain expert.This study focuses on early detection of Lassa fever using a fuzzy expect system. The main objective is to

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design an expert system that can be use as an assessment tool to diagnose Lassa fever at early stage. This system is built using rule-based approach that incorporates the use of fuzzy logic. In section II,the literature review on the disease domain and Fuzzy Expert System (FEM) is presented.

2.0 Literature Review

The Lassa virus (an arenavirus) is found in West Africa, where it sometimes causes a severe hemorrhagic illness called Lassa fever.

Lassa fever is caused by a single stranded RNA virus and is a disseminated systemic primary viral infection[10]. The main feature of fatal illness is impaired or delayed cellular immunity leading to fulminant viraemia [11].

The disease is mild or has no observable symptoms in about 80% of people infected, but 20% have a severe multisystem disease. The incubation period is 6-21 days. The virus is excreted in urine for three to nine weeks from infection and in semen for three months [12].

The mode of presentation of Lassa fever can be non-specific and hence the difficulty in clinical diagnosis of some cases. However the classical modes of presentation include high grade fever >38°C, sore throat, retrosternal pain, cough, odynophagia, conjunctivitis, petechial hemorrhages, abdominal pains, vomiting and diarrohea. It could also present with headache, joint pains and facial swellings. The symptoms usually set in between 1^{st} and 3rd week of exposure to the Lassa virus [1]. Throat examination usually reveals exudative pharyngitis and urinalysis often is characterized by proteinuria. Neurological symptoms (tremors, convulsions, meningitis symptoms etc) are not commonly present at this early stage, however, sensorineural hearing loss sometimes presents. Recent research suggests that early sensorineural hearing loss and probably early manifestation of other Central Nervous system (CNS) features depict poor prognostication [13,14]. Sensorineural hearing deficit is a feature of the disease: it was found in 29% of confirmed cases compared with none of febrile controls in hospital in patients [15].Laboratory diagnosis has traditionally been by the indirect fluorescent-antibody (IFA) test. However, enzyme-linked immunosorbent assays (ELISAs) for Lassa virus antigen and immunoglobulin M (IgM) and G (IgG) antibodies have been developed that are thought to be more sensitive and specific.

A fuzzy expert system is an expert system that uses fuzzy logic instead of conventional logic. It uses a collection of fuzzy membership functions and rules to facilitate reasoning. Since it uses rules, it falls into the category of rule-based expert systems [16]. Rules can easily demonstrate human thinking as they are easily formulated [17]. Fuzzy expert systems are used to provide non experts with some expert's skills [16]. Figure 1 represent a simple fuzzy expert system.

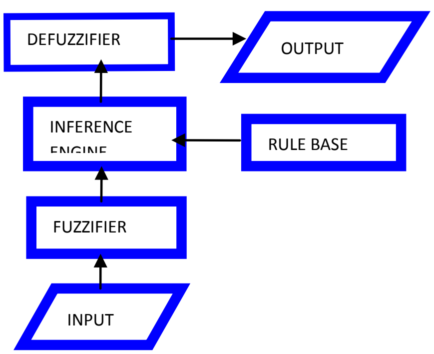

Figure 1: Fuzzy Expert System Architecture.

The fuzzy expert system followed three transformation stages; fuzzification, rule-based and defuzzification processes which was represented in Figure 2. Fuzzification is the process of finding the fuzzy value of a crisp one. Rule-based is a process which involves deriving conclusions from existing data [16]. It determines the degree to which the antecedent is satisfied for each rule. Defuzzification is the process of converting fuzzy output sets to crisp values.

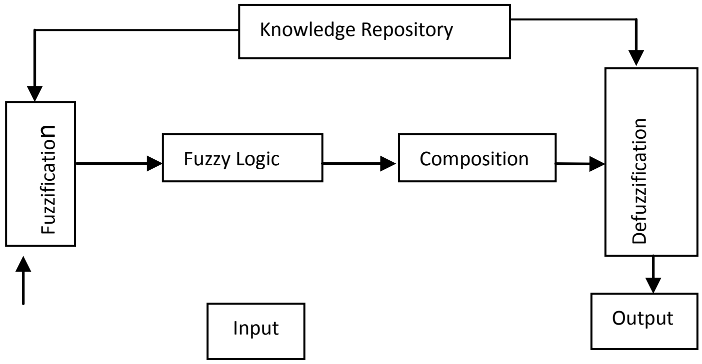

Figure 2: A Model for Fuzzy Logic of LF

Fuzzy logic was developed by LotfiZadeh a professor at the University of California,
Berkley. It is useful for real world problems where there are different kinds of uncertainty [18]. One kind of uncertainty is fuzziness that is no sharp transition from complete membership to non membership.
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 [19]. 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 [20].

3.0 Methodology

In addition to complete medical history and physical examination, diagnostic procedure of Lassa fever virus includes laboratory tests such as emzyme- linked immunosorbent serologic assays (ELISA), which detect immunoglobulin M (IgM) and immunoglobulin G (IgG) antibodies as well as Lassa antigen. It can also be detected by reverse transcription- polymerase chain reaction (RT- PCR). The doctor used the diagnostic information to detect the virus. In designing our model for the diagnosis of Lassa fever, a set of parameters (symptoms) are collected and inputted into the system which are to be used for the diagnosis. In this research work, we present an architecture model for the diagnosis of Lassa Fever as shown in figure 3. It comprised of Back-End Engine (Knowledge Warehouse) which is composed of the knowledge of the medical expert which aid the diagnosis of Lassa fever, Front-End Engine (Inference Engine and Decision Support Engine) which is composed of the following: Application modules developed by expert programmer (knowledge Base Administrator) for mining and reporting the knowledge resident in the knowledge warehouse for the end-users and casual users to evoke and Web Engine for online and real time creation and management of the knowledge warehouse by the knowledge warehouse application (KWA). The input variables are; Fever (F), Abdominal Pain (AP), Proteinuria(P) and Thrombocytopenia (T). We selected 5 suspected patients with Lassa fever; we incorporate fuzzy approach and developed a web-based fuzzy expert system for diagnosis of Lassa Fever (LF). In order notto leave the system design incomplete, forlogicalmodeling, Unified ModelingLanguage(UML) was used in order to achieve a conciseand systematic modelling as represented in Figures 4 and 5. For physical modeling,the system was developed using PHP as ascripting language to produce HTML pages for the web server with MySQL relationaldatabase on Apache Sever under windows 7 and graphical representation respectively. Fuzzy logic approach was applied to diagnosis of LF using the architecture in figure 3. The next phase is to perform defuzzification in order to evaluate the crisp output; defuzzificationis the process of producing a quantifiable result in fuzzy logic,given fuzzy sets and corresponding membership degrees. Defuzzification is interpreting the membership degrees of the fuzzy sets into a specific decision or real value. In this research Root Sum Square (RSS) is represented in equation (1) were used.

$$\mathrm{RSS} = \sum_{j=1}^{m} \mathrm{R}_\mathrm{j}^2 \quad (1)$$

Where $R_j$represents a fired rule and j = 1,2---m represents the number of fired rules for a particular diagnosis.

4.0 Result and Discussion

In designing our model for diagnosing Lassa fever, we make use of four (04) input parameters; Fever (F), Proteinuria (P), Throbocytopenia (T), and Abdominal Pain (AP).

These are made available for fuzzification. The tests are performed to determine if the patient is having Lassa Fever Virus (LFV) or not. These parameters constitute the fuzzy parameter of the knowledge base. The fuzzy sets of parameters are represented by 'p', which is defined as

$p= \{p_1, p_2,\ldots p_n\}$ --------------(2)

where p_1 represent jth parameter and n is the number of parameter.The knowledge base has the entire set of the database. The inference engine has the production rules that are fuzzy logic driven. The filters are present in the decision support engine for ranking patients in terms of the presence or absence of Lassa virus. The behavioral impairment takes an input and output report of inference engine and applies the objective rules to rank the individual on the presence of Lassa virus. This is represented in the computer system in the form of binary were 1 represent the presence of Lassa virus(input vector) and 0 represent otherwise (symptoms vector). The rule base consists of a set of fuzzy propositions and is derived from the knowledge base of the medical expert.Clinical record of 5 patients were collected and analyzed . The diagnosis variables; F, AP, P and T were used. Table 1 shows the original data set that were validated.The data were fuzzified into the fuzzy value range by the domain expert as show in Table 1

Table 1: Sample data set

Serial No	F (^{0}C)	AP(NRS)	P(mg/dl)	T(μL)
1	36.1	2	30	150
2	37.8	5	100	100
3	39.5	10	300	80
4	36.1	2	10	100
5	39.5	4	100	150

Upon determination of fuzzy membership functions and constructing a rule base withdomain expert advice made up of 18 rules each rule is made up of 4 input variables and one output variable as shown in Table 2, we developed a fuzzy inference system which consists of four inputs variables and an output variable which show the outcome of a diagnosis called Lassa fever suspiciouswhichisrepresented by 'f(lfs)'. And this is determined based on equation (3).

$$F(lfs) = \begin{cases} \text{No suspicion,} & \text{if } f(lfs) < 0.47 \\ \text{Suspicion,} & 0.48 \leq f(lfs) \leq 0.65 \\ \text{High suspicion,} & 0.66 \leq f(lfs) \leq 1.0 \end{cases} \quad (3)$$

Unified modeling language (UML) is a tool used to capture and model some of the functionalities in the system. Here we make use of use-case diagram, and sequence diagram. The use-case is the description of the systems behavior from a user point of view. The sequence diagram illustrates the process described in the use-case.

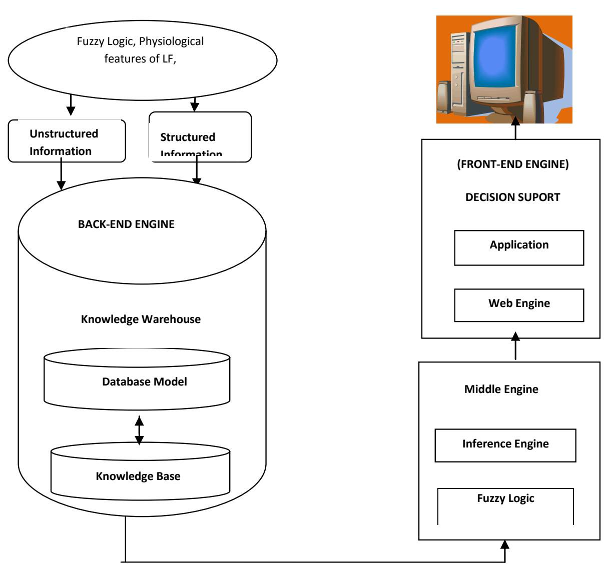

Figure 3: Architecture Of The System

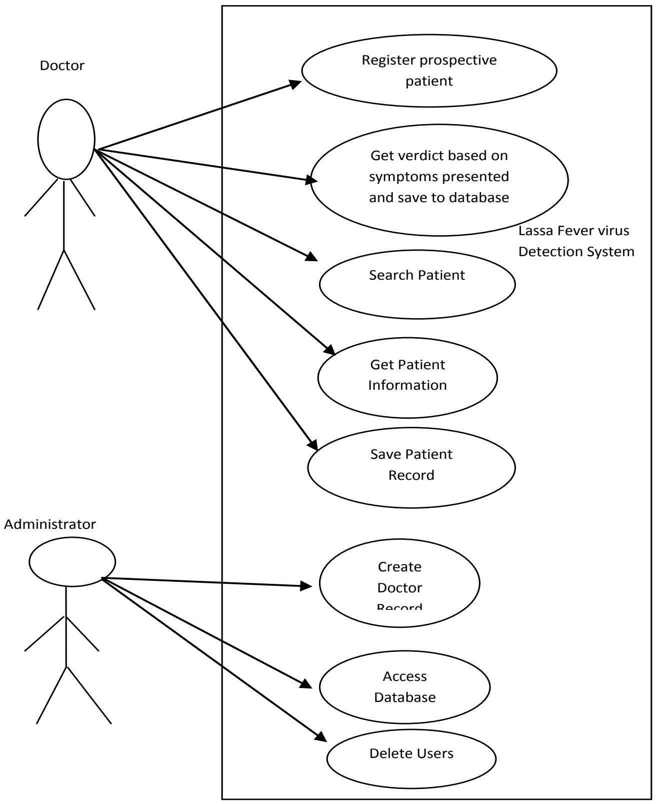

Figure 4: use- case diagram.

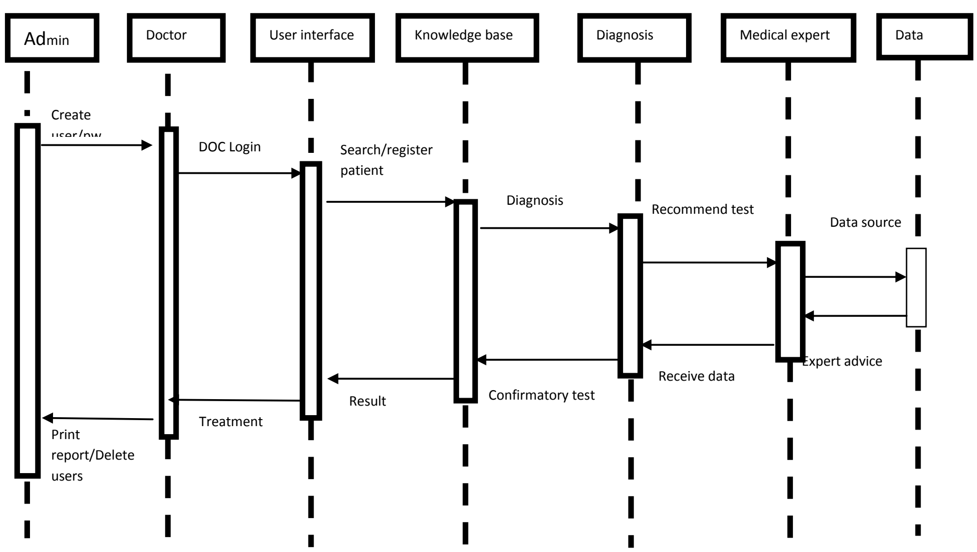

Figure 5: Sequence diagram

Table 2: Sample Rule for the proposed system for fuzzy expert model.

Rule No	**IF**				**THEN**
	F	**AP**	**P**	**T**	**LASSA FEVER SUSPICION**
1	Normal	Mild	Mild	Normal	No suspicion
2	Low-grade	Moderate	Moderate	Low	Suspicion
3	High-grade	Severe	Severe	Low	High suspicion
4	Normal	Moderate	Very severe	Normal	No suspicion
5	High-grade	Mild	Mild	Low	Suspicion
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18	Low-grade	mild	mild	normal	No suspicion

The above data in Table 1 were fuzzified into fuzzy value range as shown in Table 3 below by the domain expert.

Table 3: Fuzzified Table of Patient Data.

Sn	**F**	**AP**	**P**	**T**
1.	0.10 **Normal**	0.28 **Mild**	0.11 **Mild**	0.4 **Normal**
2	0.10 **Low-grade**	0.55 **Moderate**	0.14 **Moderate**	0.3 **Low**
3	0.11 **High-grade**	1.0 **Severe**	0.23 **Severe**	0.3 **Low**
4	0.10 **Normal**	0.28 **Mild**	0.11 **Mild**	0.3 **Low-**
5	0.10 **High-grade**	0.46 **Mild**	0.14 **Mild**	0.7 **Low**

From the predefined rules above and using equation (1), the suspicion level of LFwas computed as shown in table 4.

Table 4: diagnostic Results

Sn	**F**	**AP**	**P**	**T**	**FIS**	**DIAGNOSIS**
1.	0.10	0.28	0.11	0.4	0.47	**No Suspicion**
2	0.10	0.55	0.14	0.3	0.65	**Suspicion**
3	0.11	1.0	0.23	0.3	1.0	**High suspicion**
4	0.10	0.28	0.11	0.3	0.43	**No suspicion**
5	0.10	0.46	0.14	0.7	0.63	**Suspicion**

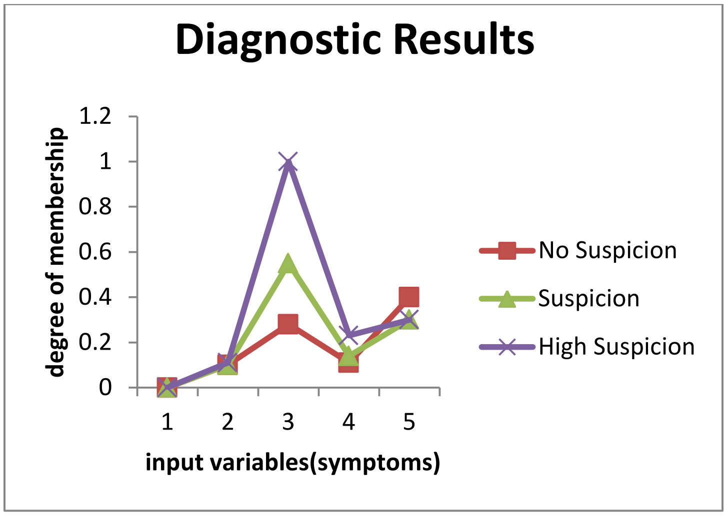

Figure 6: A graph showing the diagnostic Results

5.0 Conclusion

We designed a web-based fuzzy expert system for diagnoses of Lassa Fever (LF) using fuzzy logic approach. This system was able to detect the Lassa Fever Virus early. And early detection of a Lassa fever case improves protection of staff from nosocomial Lassa virus transmission.

We considered various symptoms (parameters) that lead to different ranges of suspicion of Lassa Fever Virus (LFV) which provide a decision support platform that will assist medical experts in early diagnosis of LF. This system is fast, efficient and reliable hence reduces time and less work for doctors during diagnosis.

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