A Decision Support System Model for Diagnosing Tropical Diseases Using Fuzzy Logic

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ABSTRACT

Malaria, Typhoid, Tuberculosis, Sexually Transmitted Diseases, Urinary Tract Infection, Yellow fever, Hepatitis-B, Leprosy and Chicken Pox are the existing tropical diseases that are considered in this work. In sub-Saharan Africa, the application of fuzzy logic to the diagnosis of these diseases is still very sparse and in some places practically non-existent. Fuzzy set theory and fuzzy logic are very suitable and applicable basis for developing knowledge-based systems in medicine for diagnostic tasks. Our design demonstrate how information technology and medicine can successfully operate together using differential diagnosis by applying fuzzy logic to medical informatics. We verified our approach with trials with the following systems which are: A fuzzy expert system for syndromes differentiation in oriental traditional medicine, an expert system for lung diseases using fuzzy logic, case based reasoning for medical diagnosis using fuzzy set theory, a diagnostic system combining disease diagnosis of western medicine with syndrome differentiation of oriental traditional medicine, a fuzzy system for classification of western and eastern medications, and a fuzzy system for diagnosis and treatment of integrated western and eastern medicine. Results from our experiments showed that fuzzy logic is known to resolve the conflicts arising from ambiguity, uncertainty and imprecision of information [1].

Keyword: Malaria, Fuzzy Logic, Medicine, System, Expert System.

1. INTRODUCTION

Tropical diseases are associated with a high level of mortality rate and also they are very common in developing countries. The tropical diseases under consideration in this study can be classified into respiratory tract infection (Cough, Catarrh, Chest pain, difficulty with breathing, hemoptysis (coughing up blood)), gastrointestinal tract (Abdominal pain, vomiting, diarrhea, constipation, yellow discoloration of the eye, anorexia, poor appetite). Others include genito urinary tract (Pain on urination, frequent urination, lower abdominal pain, abnormal discharge, itching in genital region, blood in urine), and constitutional (Fever, chills, weight loss); these tropical diseases listed above have some similar symptoms which makes it difficult sometimes for Doctors to diagnose based on the fact that they have to consider a lot of information before they can make the right diagnosis. Our approach is to develop a methodology that makes it easier for medical personnel to carry out diagnosis by weighing each symptom with respect to the disease in question using generalized fuzzy soft set (GFSS).
2. RELATED WORKS

In the early manifestations of telemedicine, African villagers used smoke signals to warn people to stay away from the village in case of serious disease. In the early 1900s, people living in remote areas in Australia used two-way radios, powered by a dynamo driven by a set of bicycle pedals, to communicate with the Royal Flying Doctor Service of Australia. Fuzzy Logic is a logical system which aims at a formalization of approximate reasoning [2].

Fuzzy logic and its hybrids have also been applied in the modeling of medical diagnosis systems, for the following conditions [1]: malaria [3, 4], viral hepatitis [4], cardiovascular diseases [5] and ontology-driven differential diagnosis [6]. The application of fuzzy logic was discussed in [7]. Its application in non-invasive diagnosis of myocardial ischemia is discussed in [8], while [9] utilized it in neural network analysis of muscle contraction. [10] Also used fuzzy logic in implementing a decision support system for automated diagnosis and classification of ultrasound kidney images. [11] applied soft computing and carried out a study on web based intelligent self diagnosis medical system and [12] also applied soft computing in a neuro-case-rule base hybridization in medical diagnosis. [13] Applied computing in the development of an expert system for a computer aided medical diagnosis system based on principal component analysis and artificial immune recognition system classifier algorithm. [14] Also talked about the application of knowledge based systems in medical diagnosis, the application of fuzzy logic and reasoning in medical diagnosis was discussed in [15].

My motivation came about when I realized that some doctors have not improved on their knowledge gained in university that is some Doctors are not familiar with some of the new changes in medicine and in the human health; for this reason these doctors can put the patient’s life at risk. More so, when a patient goes to a hospital, sometimes they have difficulty explaining how they feel to the doctor, sometimes the doctor would waste time attending to the patient based on the fact that there are so many patients and limited doctors; for these reasons we were motivated to look into medical informatics and how to apply technology to medicine so as to be able to save more lives and to permanently bring information technology to the medical field. My expected result is to have a user friendly working decision support system interface that can run on any platform in any clinic. The system should contain the symptoms of the ten tropical diseases that are being considered which are: Malaria, Typhoid, Tuberculosis, Sexually Transmitted Diseases, Urinary Tract Infection, Yellow fever, Hepatitis-B, Leprosy and Chicken Pox. The system should be able to diagnose a patient based on the patient's complaints and also the level of severity of the patient's complaints.

3. METHODOLOGY

The study follows the generalized fuzzy soft set (GFSS) methodology as highlighted in Fig.1 below. The architecture contains mainly six components:

a. Login: this enables the Medical Doctor to be able to access the decision support system. The Doctor logs in with a valid username and password.

b. GFSS Interface: this provides a graphic interface showing the symptoms considered and their respective acronyms.

c. Enter Patient’s Symptoms into the system: based on the interaction between the patient and the medical Doctor, the patient’s symptoms (in relation to the symptom intensity) is entered into the system.

d. Knowledge Base: the symptoms of the patient is keyed into the system and based on the weights of the symptoms stored in the knowledge base, the symptoms are Fuzzified.

e. Interference Engine: this is where the Fuzzified value is defuzzified in the decision support system model.

f. Results Table: the result is displayed which shows the diagnosis of the patient.
3.1 Data Collection

We gathered data by interacting with various Medical Doctors who are experts in diagnosing tropical diseases so as to be able to gain heuristic knowledge on the diseases I considered. We considered three Medical Doctors in Nigeria both from a private hospital and the state hospital in Lagos. Questionnaires were also used alongside interaction with these Doctors.

The questionnaires contained information on all the symptoms and complications that can be seen in a patient that has any of the ten tropical diseases We considered that is, evaluation of the ways in which each Doctor carries out his/her diagnosis; it also contains the symptoms grouping of tropical diseases. The most important aspect of the data collection in the questionnaire is the significance of specific symptoms over another symptom of a particular disease under consideration that is, the ratio of the importance of one symptom over another on a scale of 1 to 9.

3.2 Analysis of Data

The analysis of data in this project involved the following:

a. Evaluation of weights
b. Application of generalized fuzzy soft sets in a case study
c. Software Design and Coding
d. Testing and evaluation

3.2.1 Evaluation of Weights

Pair wise comparison matrix was used to evaluate the true weight of the symptoms. This is done from the top level of the hierarchy to the bottom level in order to establish the overall priority index. The aggregation of these weights using a modified fuzzy inference can be adapted from [16, 17, 18].

**Step1: Create a matrix table for each disease based on their major symptoms**

This step involves the ratio of importance of one symptom over another on a scale of 1 to 9. That is for instance, based on my interaction with Doctors, the importance of fever over other symptoms of malaria is 8. Below is a table showing the matrix table created based on the major symptoms of malaria and the importance of one symptom over another.

<table>
<thead>
<tr>
<th></th>
<th>FEVER</th>
<th>HEADACHE</th>
<th>GENERAL BODY WEAKNESS</th>
<th>POOR APPETITE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEVER</td>
<td>1</td>
<td>8/3</td>
<td>8/3</td>
<td>8/2</td>
</tr>
<tr>
<td>HEADACHE</td>
<td>3/8</td>
<td>1</td>
<td>1</td>
<td>3/2</td>
</tr>
<tr>
<td>GENERAL BODY WEAKNESS</td>
<td>3/8</td>
<td>1</td>
<td>1</td>
<td>3/2</td>
</tr>
<tr>
<td>POOR APPETITE</td>
<td>2/8</td>
<td>2/3</td>
<td>2/3</td>
<td>1</td>
</tr>
</tbody>
</table>

**Step 2: calculate the eigen value for each cell**

This is done by dividing the particular cell by the column total of each cell with the formula below:

\[
E_{ij} = \frac{V_{ij}}{T_j}
\]

Where \(E\) = eigenvalue of cell \(a_{ij}\)

\(V\) = the value of the pairwise comparison matrix for cell \(a_{ij}\)

\(T\) = the sum of the values on column \(j\)

**Step 3: sum up the rows and columns**

After calculating the Eigen values with the formula above, a new matrix table is created. This step involves the summing of the rows and columns so as to get the row and column total. Note that the sum of the row total and column total should have the same value.

**Step 4: Calculation of the Eigen vectors**

This step involves the calculation of the Eigen vectors which gives you the calculated weights for each major symptom that would be put into the database so as to be able to work with the generalized fuzzy soft set in diagnosing of patients. The Eigen vector is calculated by dividing the row total by \(n\).

\[
\lambda k = \frac{\sum E_{kj}}{n} \quad \text{i.e. } \lambda k = \text{row total} / n
\]

Where

\(\lambda k\) = the eigenvector corresponding to variable \(k\)

\(\sum \lambda k = 1\)

\(E_{kj}\) = the eigenvalue of cell \(a_{ij}\) \((j = 1, 2, \ldots, n)\)

\(n\) = the sum of the row total
3.2.2 Application of generalized fuzzy soft sets (Fuzzification) in a case study

The method in which the generalized fuzzy soft set can be applied can be seen extensively in [19]. A rule base is created which shows the symptoms extracted for the fuzzy linguistic function. These functions are gotten based on the definition of symptom intensities by medical doctors. These linguistic tags are coded into the system as production rules and it is based on the fuzzy linguistic function shown below in a tabular form:

<table>
<thead>
<tr>
<th>Range</th>
<th>Symptom Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No sign</td>
</tr>
<tr>
<td>0-0.9</td>
<td>Very mild</td>
</tr>
<tr>
<td>1.0-1.9</td>
<td>Mild</td>
</tr>
<tr>
<td>2.0-2.9</td>
<td>Moderate</td>
</tr>
<tr>
<td>3.0-3.9</td>
<td>Severe</td>
</tr>
<tr>
<td>4.0-4.9</td>
<td>Very severe</td>
</tr>
</tbody>
</table>

A patient was picked at random and the Doctor observed that the patient to have headache (moderate), fever (severe), poor appetite (severe), vomiting (mild), abdominal pain (moderate) and general body weakness (severe). The generalized fuzzy soft set formula below was used. The formula converts the numerical weights calculated above into fuzzified weights.

\[ S(F_\rho, G_\delta) = M(F, G) . M(\rho, \delta) \]

Where

\[ M(F, G) = \max_i M_i(F, G), \]

where \( M_i(F, G) = 1 - \sum |F_i - G_j| \)

\[ \sum (F_i + G_j) \]

\[ = 1 - \sum \frac{|weight \ on \ rowij - weight \ on \ rowij|}{\sum (weight \ on \ rowij + weight \ on \ rowij)} \]

This means that you subtract the value in row1 column1 on a GFSS table from the value in row1 column1 on a patient’s complaint table. The same thing would be done for other rows and columns and

\[ M(\rho, \delta) = 1 - \sum \frac{\rho_i - \delta_j}{\sum (\rho_i + \delta_j)} \]

\[ = 1 - \sum \frac{\text{maximum weight on rowi} - \text{maximum weight on rowi}}{\sum (\text{maximum weight on rowi} + \text{maximum weight on rowi})} \]

\[ = 1 - \sum \frac{\text{weight on rowij} - \text{weight on rowij}}{\sum (\text{weight on rowij} + \text{weight on rowij})} \]

Hence \( F_\rho = \{(F(e_i), \rho(e_1)), i = 1, 2, \ldots, m) \)

\( G_\delta = \{(G(e_i), \delta(e_1)), i = 1, 2, \ldots, m) \)

Let \( U = \{x_1, x_2, \ldots, x_n\} \) be the universal set of elements

\( E = \{e_1, e_2, \ldots, e_m\} \) be the universal set of parameters

NOTE: In this project, the set of elements \( x_1, x_2, \ldots, x_n \) represent the tropical diseases that were considered and the set of parameters \( e_1, e_2, \ldots, e_m \) represent the complaints of the patient.

Step 1:
Based on the symptoms the patient gave the Doctor, ‘Fij’ is created which is the equating of the weights calculated above for the patient’s symptoms to the ten diseases.

That is,

\[ F(em) = \{(x_n/\text{the weights of headache for the ten tropical diseases), the range of symptom intensity of the patient’s headache}) \]

\[ F(HDC) = \{(X1/0.1875, X2/0.125, X3/0.001, X4/0.25, X5/0.001, X6/0.001, X7/0.001, X8/0.001, X9/0.001, X10/0.001), 3.0} \]

Step 2:
The next step is to create matrix tables for both the patient (Fij) and the GFSS table (Gij) based on the symptoms. The patient’s table is created by multiplying the symptom intensity range of a symptom by the weights.

For example: to get the value of row x1 (malaria) column e1 (headache), the weight of headache for malaria which is = 0.1875 is multiplied by the intensity of the patient’s headache which is moderate = 3

Therefore, \( x_1 e_1 = 0.1875 \times 3 = 0.5625 \)

Step 3:
The next step is to calculate \( M(\rho, \delta) \) that is,

\[ M(\rho, \delta) = 1 - \frac{\sum |\rho_i - \delta_j|}{\sum (\rho_i + \delta_j)} \]

and

\[ M(F, G) \text{ for all the diseases under consideration that is,} \]

\[ M(F, G) = \max_i M_i(F, G), \text{ where } M_i(F, G) = 1 - \frac{\sum |F_i - G_j|}{\sum (F_i + G_j)} \]

\[ = 1 - \frac{\text{weight on rowij} - \text{weight on rowij}}{\sum (\text{weight on rowij} + \text{weight on rowij})} \]
Step 4:
The next step is to check for the relationship between $M(\rho, \delta)$ and $M(F, G)$ that is, show the relationship between the two generalized fuzzy soft set (GFSS). From my calculation $M(\rho, \delta) = 0.42$, the only disease that is similar to this is that of Malaria. Therefore based on this calculation, the patient is suffering from Malaria.

\[ S(F_\rho, G_\delta) = M(F, G) \cdot M(\rho, \delta) = 0.42 \]

In cases where there is more than one calculated $M(F, G)$ that is similar to the $M(\rho, \delta)$ GFSS, laboratory tests like blood count, blood film, virus screening etc. for the related diseases can be carried out to determine the major disease.

3.2.3 Software Design and Coding
The software design and coding of the decision support system was done using JAVA.

4. TESTING AND EVALUATION
The system was tested thoroughly so as to ensure that the system produces the right diagnosis and result.

3.0 Expected Impacts of the System
The following system impacts shows how the medical diagnosis architecture can be useful in Nigeria.

4.1 Target
UNICEF recent report [20] indicates that 52% of Nigerians in rural areas consists of women and children. It is targeted to remote areas in Nigeria where the number of patients are many compared to the number of Doctors readily available to attend to them that is, very poor Doctor – to – patient ratio. This way, Doctors can attend to more patients within a short period of time.

4.2 Reduce Cost of Health Care
This proposed system would help improve health care by being able to address minor illness on time. Another impact of this project to rural areas is also to reduce the level of mortality rates caused by the priority tropical diseases conditions.

4.3 User Friendliness
The interface of the system is made to be user friendly so that medical doctors would be able to interact with the GFSS interface without the aid of any IT administrator.

5. CONCLUSION
Malaria, Typhoid, Tuberculosis, Sexually Transmitted Diseases, Urinary Tract Infection, Yellow fever, Hepatitis-B, Leprosy and Chicken Pox are the existing tropical diseases that were considered in this work. The development of this differential diagnosis will help to benefit countries in remote places where healthcare services are limited. Based on the linguistic tags, a fuzzy rule base is created; in the fuzzy inference engine the generalized fuzzy soft set is used to generate the suspected diseases.

The contribution of the system that was built and implemented is to improve the performance of Doctors in the aspect of diagnosing of tropical diseases and also to reduce the amount of time a patient spends in the clinic.

REFERENCES


