A Web Based Decision Support System by Fuzzy Expert Systems for Diagnosis of Typhoid Fever

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Abstract
Typhoid fever is a disease that is caused by bacteria called salmonella typhi. It is also known as Enteric fever, Typhoid fever is been characterized by high fever, constipation, diarrhoea, abdominal pain, etc. It is often treatable when diagnosed early, but if left untreated could lead to other medical complications like intestinal haemorrhaging which may require major surgeries and could even lead to death. This paper proposes a method of diagnosis of Typhoid Fever using Fuzzy Logic. Although there are many systems in existence, this work is however based on the assumption that a system with a higher number of inference rules will make diagnosis a lot easier. An experimental study of the proposed system was conducted using medical records of TF patients obtained from the Federal Medical Center, Owo, Ondo State-Nigeria over a period of six months and the results of the study were found to be within the range of predefined limit as examined by medical experts. Standard statistical metrics were used to measure the efficiency of the proposed system and the results obtained show that the proposed system is 94% efficient in providing accurate diagnosis.

Keywords: Fuzzy logic, Typhoid fever, Salmonella, Medical diagnosis, Knowledge base

Introduction
Typhoid Fever (TF) remains a major public health problem in developing countries of the world even in the twenty first century (Lin et al., 2000; Otegbayo, Daramola, Onyegbutulem, Balogun, & Oguntoye, 2003). Unacceptable morbidity and mortality are still recorded in developing countries in spite of the availability of several drugs over the years for the treatment of TF (Otegbayo, 2005). The process of disease diagnosis and management is complex because of the numerous variables involved. It is further complicated by the imprecision and uncertainty associated with such variables (Djam, Wajiga, Kimbi, & Blama, 2011; Nguyen & Walker, 1997). Since the effectiveness of the therapy for a given disease is highly dependent on the level of accuracy of its diagnosis, these complexities in medical practice make the conventional quantitative diagnosis approaches inadequate and hence call for new technique.

Computer tools help to organize, store and retrieve appropriate medical knowledge needed by medical practitioners to deal with difficult cases and suggest appropriate diagnosis, prognosis, and therapeutic decisions (Szolovits, Patil, & Schwartz, 1988). Expert System (ES) is an intelligent interactive computer based decision tool that uses facts and rules to solve difficult real life problems based on the knowledge acquired from one or more human expert(s) in a particular field. ESs have user friendly interfaces which make them highly interactive in nature and provide accurate and timely solutions to difficult real life problems (Durkin, 1994). In order to address the inadequacies of the conventional methods of medical diagnosis, medical expert systems were proposed.

Fuzzy Logic (FL) has been identified as a substantial soft computing tool that is used to represent the knowledge of an expert in a computer program such that the program can solve problems in a manner that is similar to human expert. That is, FL finds its strength in providing accurate solutions to problems that involve the manipulation of several variables (Ojokoh, Omisore, Samuel, & Ogumniyi, 2012). FL has been used extensively for the implementation of ESs in the field of medicine due to its ability in handling the imprecision and uncertainty inherent in medical records. Fuzzy expert system incorporates elements of FL which provides consistent, accurate, and timely results (Wainer & Sandri, 1999).

This research proposes a WBDSS driven by FL for the diagnosis and management of TF based on the

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principles and practices of medical diagnosis. The system was developed with the aim of providing a decision support platform for medical practitioners, TF researchers, and health care providers in developing countries of the world. The proposed system will assist medical personnel especially in rural areas where there are shortage of doctors in providing quality health care services. The architecture of the proposed system as presented in Fig. 1 consists of a KB that houses the database and the rule base, a FIS that does the actual diagnosis, and a World Wide Web component which makes the proposed system accessible over the Internet.

The remainder of this paper is organized as follows: Section 2 presents review of related work; Section 3 presents the architecture of the proposed system, method and materials adopted by the research; Section 4 presents the experimental study and result of the proposed system. Section 5 presents the evaluation of the proposed system; Section 6 presents the conclusion and recommendations. Typhoid fever is a disease that is caused by bacteria called salmonella typhi. It is also known as Enteric fever. Typhoid fever is characterized by high fever, constipation, diarrhoea, abdominal pain, etc. It is very common in developing countries like Ghana and according to Crump and Mintz (2010), it has caused an estimated 21.7 million illnesses and 217,000 deaths. In 2013, there were 161,000 reported deaths from typhoid fever.

Typhoid fever is often treatable when diagnosed early, but if left untreated could lead to other medical complications like intestinal haemorrhaging which may require major surgeries and could even lead to death. To this end, there is a need to accurately diagnose the disease.

Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based. The idea of fuzzy logic was first advanced by Dr Lotfi Zadeh of the University of California at Berkeley in the 1960s. This implies that a fuzzy control system is a control system based on fuzzy logic—a mathematical system that analyses analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0. In fuzzy logic, 0 and 1 are considered extreme cases and one is often expressed or evaluated as a degree of the other. For instance, a person cannot be 100% ill but could suffer a high degree of illness likewise a person may not exhibit the symptoms of an ailment but may suffer a degree of that ailment. In building inference engines, one has to determine the degree to which the patient exhibits a symptom and then aggregate these to determine whether or not the patient suffers a particular ailment.

Salmonella enteric serotype typhi is the aetiological agent of TF, a multi systemic disease with protein manifestations and initial lesions in the bowel. The biggest challenge in the management of TF is perhaps the emergence and spread of multi drug resistance strains of the bacterial causing TF, and the complication with malaria co-infection leading to significant morbidity and mortality (Bhan, Bhal, & Bhatnagar, 2005; Bhutta, 1996; Gupta, 1994; Siddiquia, Rabbania, Hasanb, Nizamic, & Bhuttau, 2006). The above challenge of drug resistance has been attributed basically to the flows associated with the orthodox approach to TF diagnosis.

Computer technology can be used to reduce the number of mortality and minimize the waiting time to see a medical practitioner. Computer program developed by emulating human intelligence could be used to assist doctors in making timely and accurate decisions regarding patients’ diagnosis. Such programs are known as medical decision support systems and they help health care professionals make timely clinical decisions (Shortliffe, 1987). Medical decision support systems operate on medical data using the knowledge of a medical expert in diagnosing patients’ conditions as well as recommending effective treatments for patients (Wan & Fadzilah, 2006).

Many intelligent systems have been developed for the purpose of enhancing health care delivery, providing better care facilities, and reducing the cost of health care services. As expressed by some studies (Alexopoulos, Dounias, & Vemmos, 1999; Boursal, Giakoumakis, & Papakonstantinou, 1999; Mahabala, Chandrasekhar, Baskar, Ramesh, & Somasundaram, 1992; Manickam & Abidi, 1999; Ruseckaite, 1999; Alexopoulos, Dounias, & Vemmos, 1999; Bourlas, Giakoumakis, & Papakonstantinou, 1999; Mahabala, Chandrasekhar, Baskar, Ramesh, & Somasundaram, 1992; Manickam & Abidi, 1999; Ruseckaite, 1999; Zelic, Lavrac, Najdenov, & Rener-Primec, 1999), intelligent systems were developed to assist users (doctors and patients) provide early diagnosis and prediction to prevent serious illness. Even when the system is equipped with “human” knowledge, it will never replace human expertise, since humans are required to frequently monitor and update the system’s knowledge. Therefore, the roles of medical practitioners are important to ensure system’s validity (Wan et al., 2006).

Early studies in intelligent medical systems such as CASNET, MYCIN, PIP, INTERNIST-I, have been shown to outperform manual practices of diagnosis in several domain (Shortliffe, 1987). CASNET (Causal Association NETworks) was developed in early 1960’s as a general tool for building expert system for the diagnosis and treatment of diseases. CASNET major application was the diagnosis and recommendation of treatment for glaucoma. MYCIN
was developed in the early 1970’s to diagnose certain antimicrobial infections and recommend drug for treatment. It is made up of the following; explanation facility, knowledge acquisition facility, teaching facility, and system building facility. Personal Illness Program (PIP) was developed in 1970’s to simulate the behavior of an expert nephrologist in taking the history of present illness of a patient with underlying renal disease. The work on INTERNIST-I in the early 1982’s was concentrated on the investigation of heuristic methods for imposing differential diagnostic task structures on clinical decision making. It was applied in the diagnosis of internal medicine (Wan et al., 2006).

In 1990’s, studies in intelligent system was enhanced by combining two or more techniques. Later, Case Based Reasoning (CBR) was employed to utilize the specific knowledge of previous experience and problems or cases. The system can be used by patients to diagnose themselves without having to make frequent visit to doctors and as well medical practitioners to extend their knowledge in domain cases such as breast cancer (Manickam et al., 1999).

FL is a branch of Artificial Intelligence (AI) techniques that deals with uncertainty in knowledge that simulates human reasoning in an incomplete or fuzzy data (Meng, 1996). FL is basically aimed at providing approximate reasoning (Zadeh, 1965). The concept of fuzzy logic has found its application in the modeling of medical diagnosis systems for malaria (Obot & Uzoka, 2008; Praveen et al., 2008), viral hepatitis (Obot & Uzoka, 2008), cardiovascular diseases (Akinyokun, Obot, Uzoka, & Andy, 2010), and ontology-driven differential diagnosis (Garcia-Crespo, Mencce, & Gómez-Berbí, 2010).

The World Wide Web (WWW) has been a major platform for information sharing and productivity enhancement over the years. Research shows that the number of medical experts to patients is grossly inadequate. This inadequacy has placed so much demand on the few available medical experts, increased cost of medical services, and as well denied several patients of quality and timely health care services (Jarvis-Selinger, Bates, Araki, & Lear, 2011). The WWW allows information sharing, collaboration between medical practitioners, online discussion, online treatment and diagnosis among others (Wan et al., 2006). A web based system for medical diagnosis can be accessed remotely by a medical personnel regardless of his geographical location to diagnose a TF patient. Casual health workers could be trained on how to use such a system for diagnosing patients as a way of complementing the insufficient number of medical experts in developing countries.

Related Works

The need to adequately detect and diagnose typhoid fever cannot be overstated and the fact that symptoms displayed by one person who suffers typhoid, may not be present in another person, makes this task even more difficult. In recent times, different expert systems have been built to help solve this problem. These systems are built on the assumption that although a culture is the most accurate means to diagnosing Typhoid Fever, it is possible to diagnose the disease based on the manifestation of a combination of symptoms.

According to [3] though there are many similarities between Typhoid Fever and other fevers, there also exist symptoms that are peculiar to Typhoid. They also stated that the system should not only diagnose one disease, but also a few other similar diseases and should employ a robust knowledge base.

[18] however preferred to add an element of machine learning by implementing a Genetic-Neuro-Fuzzy System for the diagnosis of typhoid. The idea is that Neuro-based Fuzzy Inference Systems more accurately mimics human reasoning as the system can be trained and can also learn. This implementation is arguably one of the most suitable ways to go. [14] Specifically designed an algorithm for malaria diagnosis using fuzzy logic. The system made use of 27 rules.

In summary, all the articles which have been reviewed show that fuzzy logic is a very useful tool in the diagnosis of diseases. It has greatly improved the degree of accuracy as compared to relying solely on human efforts.

3. Methodology

The cornerstone of any development project is a thorough understanding of the business requirements. Therefore, the first step was to explore and develop a good working knowledge of the problem which in this case is to develop a system which can diagnose Typhoid Fever accurately. Typhoid fever, like most other fevers, has symptoms which are peculiar to itself and others which are shared across the different fevers and other ailments.

The goal is to build a system that can diagnose Typhoid Fever accurately. Fuzzy Logic helps us accomplish this by mimicking human reasoning with computer accuracy.

3.1 Analysis of the System

The proposed system is a Fuzzy Expert System for the diagnosis of Typhoid Fever. The system was modelled and simulated in MATLAB R2013a and implemented as an android application based on the
Java language for demonstration purposes. The advantages of the system include the following:

1. Ease of use
2. Easily scalable
3. Less Errors
4. Increased Accuracy.

### 3.2 SYSTEM DESIGN

The system was initially modelled in MATLAB R2013a with **20 input members** and **1 output member**. The system is divided into three parts which are:

1. Inputs
2. Inference Rules
3. Output

It is based on this division that the entire system was modelled. The inference rules and the database.

#### 3.2.1 INPUT MEMBERS

Input members can be described as the inputs of the system in this case, the input members are the symptoms the patient is experiencing. Usually these inputs are in crisp form (not discrete). Each input member has a membership function which in this case, is the severity of the symptom.

<table>
<thead>
<tr>
<th>Severity</th>
<th>Value Range</th>
<th>Fuzzy Value Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>1 – 4.5</td>
<td>0 – .35</td>
</tr>
<tr>
<td>Mild</td>
<td>3.8 – 7.5</td>
<td>0.28 – 0.65</td>
</tr>
<tr>
<td>Severe</td>
<td>6.8 – 10</td>
<td>0.58 – 1</td>
</tr>
</tbody>
</table>

Table 1. Symptom Severity Classification

The input members are grouped into three categories these are represented in the table below.

<table>
<thead>
<tr>
<th>TS</th>
<th>GFS</th>
<th>NTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Cough</td>
<td>Fever</td>
<td>Cold Chills</td>
</tr>
<tr>
<td>Pale Eyes</td>
<td>Headache</td>
<td>Nose Bleeding</td>
</tr>
<tr>
<td>Stomach ache</td>
<td>Nausea</td>
<td>Bleeding from eyes and ears</td>
</tr>
<tr>
<td>Rose Spots</td>
<td>Vomiting</td>
<td>Joint Ache</td>
</tr>
<tr>
<td>Malaise</td>
<td>Diarrhoea</td>
<td>Dark Urine</td>
</tr>
<tr>
<td></td>
<td>Constipation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fatigue</td>
<td></td>
</tr>
</tbody>
</table>

In the fuzzification phase, the inputs are converted from crisp form into degrees of match. This is done by applying a membership function which in this case is the triangular membership function, defined by a lower limit \(a\), an upper limit \(b\), and a value \(m\), where \(a < m < b\), given as:

\[
\mu_a(x) = \begin{cases} 
0, & x \leq a \\
\frac{x-a}{m-a}, & a < x \leq m \\
\frac{b-x}{b-m}, & m < x < b \\
0, & x \geq b 
\end{cases}
\]

#### 3.2.2 INFERENCE RULES

Inference rules are a collection of IF-THEN rules that form the basis for decision making in the system. The inference rules are what mimic the decision-making process in humans. The IF-Then statements have an “AND” connection. This implies that all conditions in each statement must be met for a specific result to be given as output. The Mamdani method was chosen due to the fact that it is well suited for human inputs.

Below are some inference rules used in the system:

1. **If (Fever is Low) then (Prognosis is None)** (1)
2. **If (Fever is Mild) then (Prognosis is FeverNoTyphoid)** (1)
3. **If (Fever is Sever) then (Prognosis is None)** (1)
4. If (Fever is Low) and (StomachAche is Low) then (Prognosis is None) (1)

5. If (Fever is Low) and (StomachAche is Mild) then (Prognosis is None) (1)

3.2.3 DEFUZZIFICATION

IN THIS PHASE, THE OUTPUT IS CONVERTED FROM MEMBERSHIP DEGREES INTO CRISP VALUES. THE CENTROID METHOD WAS APPLIED IN THIS CASE AND IS GIVEN AS:

\[ \text{COG} = \frac{\int \mu A(x) x \, dx}{\int \mu A(x) \, dx} \]

3.2.4 OUTPUT MEMBER FUNCTIONS

The output of the system is a diagnosis of whether or not the patient has Typhoid Fever. The output member function has two levels which are:

- Typhoid Free - for which the system informs the user that the patient does not have typhoid fever.
- Typhoid Present – Here, the system tells the user that they have Typhoid Fever.

4. CONCLUSION

The overall aim of the system was to develop a system that uses fuzzy logic to diagnose typhoid fever. The system was able to take patient information, take patient symptoms as input, process the said information and then provide the user with a diagnosis as an output.

The system proved to be reliable with an accuracy of 97.5% which is very impressive and thus making it one of the most reliable systems for the diagnosis of Typhoid Fever. The system made use of twenty-one (21) membership functions as inputs and has over 200 inference rules making it one of the most robust systems in the diagnosis of Typhoid Fever.

In conclusion, the project has been able to demonstrate that fuzzy logic can be used to diagnose typhoid fever and that a more robust inference engine leads to greater accuracy in the diagnostic process.

References


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