Fuzzy Expert Framework for Diagnosis of Typhoid Fever

Okpokpong Nathaniel Ntebong Celestine
Christ Apostolic University
Kwadaso
School of Technology
Kumasi, Ghana

Umar Farouk Ibn Abdulrahman
Christ Apostolic University
Kwadaso
School of Technology
Kumasi, Ghana

Itoro Akpabio
University of Uyo, Akwa
Electrical and Electronics
Department
Iborn State, Nigeria

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. The system was built with twenty input membership functions, one output membership function and about two hundred inference rules which was simulated with MATLAB R2013 and therefore 97.5 % accuracy was obtained. The centroid method was used for the defuzzification. 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 better.

Keywords
Fuzzy Logic, Fuzzification, Typhoid Fever.

1. INTRODUCTION
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 [21], it has caused an estimated 21.7million 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.

Albeit many machine learning systems have been proposed in literature to deal with the disease, yet they lack the express power to do accurate diagnosis. This research therefore proposes a better system, using fuzzy logic for accurate diagnosis.

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 analyzes 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.

2. 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 which is inadequate for any machine learning systems.

[22] proposed a new classifier was which was multi-dimensional. Intuitionalistic fuzzy terms were used to describe the medical features. Results were classified by similarity measurement. During testing of the system, the validity of the system ranged from 80% to 95%. This is really poor for a medical system as it shows a great degree of inconsistencies.

[23]developed a new diagnosis and treatment system to handle typhoid fever cases. A promising machine learning technique-decision tree algorithm was used on labelled set of typhoid fever conditional variables to generate a decision tree and classifiers for the diagnosis of typhoid fever and...
treatments were provided according to the level of severity of the disease. The accuracy of the system was measured on both the training set and testing set with the detection rates of 100% and 95% respectively. The system was implemented using Visual Basic as front end and MySQL as backend. It is important to state that while this system had a perfect score in training, it failed to reach the same score during actual implementation and testing.

In summary, despite the many different machine learning systems, there is the need for a better system to accurately diagnose typhoid fever.

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 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.

3.1.1 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 1. Symptom Severity Classification

<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>

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

Table 2 Symptom Classification

<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>
</tbody>
</table>

3.2 Fuzzification
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:

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

3.2.1 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 Severe) 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)
6. If (Fever is Mild) and (StomachAche is Mild) and (DryCough is Low) and (ColdChills is Low) then (Prognosis is FeverNoTyphoid) (1)
If (Fever is Mild) and (StomachAche is Mild) and (DryCough is Low) and (ColdChills is Mild) then (Prognosis is Typhoid) (1)

If (Fever is Mild) and (StomachAche is Mild) and (DryCough is Low) and (ColdChills is Severe) then (Prognosis is FeverNoTyphoid) (1)

If (Fever is Mild) and (StomachAche is Mild) and (DryCough is Severe) and (ColdChills is Low) then (Prognosis is Typhoid) (1)

3.2.2 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:

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

3.2.3 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.

### Table 3. Sample of Parameters Used

<table>
<thead>
<tr>
<th>Record No:</th>
<th>Bleeding Ears</th>
<th>Cold Chills</th>
<th>Confusion</th>
<th>Constipation</th>
<th>Diarrhoea</th>
<th>Disorientation / Dizziness</th>
<th>Dry Cough</th>
<th>Fatigue</th>
<th>Fever</th>
<th>Headache</th>
<th>Joint Pains</th>
<th>Loss of Appetite</th>
<th>Malaise</th>
<th>Nausea</th>
<th>Nose Bleeding</th>
<th>Pale Eyes</th>
<th>Rose Spots</th>
<th>Sweating</th>
<th>Stomach Ache</th>
<th>Vomiting</th>
<th>Weakness</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>★</td>
<td>★★</td>
<td>★★</td>
<td>★★</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>002</td>
<td>★</td>
<td>★★</td>
<td>★★★</td>
<td>★★</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>003</td>
<td>★</td>
<td>★★</td>
<td>★★★</td>
<td>★★</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>004</td>
<td>★</td>
<td>★★</td>
<td>★★</td>
<td>★★</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>005</td>
<td>★</td>
<td>★★</td>
<td>★</td>
<td>★★</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 4. Diagnostic Chart

<table>
<thead>
<tr>
<th>S/N</th>
<th>AGE</th>
<th>GENDER</th>
<th>RESULT (From Application)</th>
<th>RESULT (ACTUAL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>45</td>
<td>F</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>002</td>
<td>36</td>
<td>M</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>003</td>
<td>24</td>
<td>M</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>004</td>
<td>35</td>
<td>F</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>005</td>
<td>18</td>
<td>F</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

### Table 5 Result Summary - Positives

<table>
<thead>
<tr>
<th>Patients Tested</th>
<th>Positives (Our System)</th>
<th>Positives (Actual)</th>
<th>Accuracy Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>19</td>
<td>19</td>
<td>100</td>
</tr>
</tbody>
</table>

The above results show an accuracy of 100% in the diagnosis of people who already have typhoid fever.

### Table 6 Test Data - Negatives

<table>
<thead>
<tr>
<th>Patients Tested</th>
<th>Negatives (Our System)</th>
<th>Negatives (Actual)</th>
<th>Accuracy Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>18</td>
<td>19</td>
<td>95</td>
</tr>
</tbody>
</table>

Patients not suffering from Typhoid fever were also tested using our system and the results are below.

Average System success rating = (100 + 95) / 2 = 97.5%
Average system failure rate = 2.5%
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 and 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 research has demonstrated 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.

5. ACKNOWLEDGMENTS

We wish to acknowledge contribution of the Resident Medical Doctor of the First Care Hospital, Patasi Ghana for clarifying most of the medical terminologies.

6. REFERENCES


