Computer Aided Diagnostic Systems for Managing Typhoid Fever: A Review of Diagnosis Techniques

Oguntimilehin A.
Dept. of Computer Science
Afe Babalola University
Ado-Ekiti, Nigeria.

Abiola O.B.
Dept. of Computer Science
Afe Babalola University
Ado-Ekiti, Nigeria.

Olatunji K.A.
Dept. of Computer Science
Afe Babalola University
Ado-Ekiti, Nigeria.

ABSTRACT
Information Technology (IT) has been of immense benefits in all areas of human endeavours and medicine is not an exceptional case as it has been used in bringing hospitals to homes. A number of computer aided diagnostic systems have been developed to carry out diagnosis, provide therapy or perform both. Most of these systems are desirable due to many factors which include shortages of medical experts, hospitals and medical equipment. There are hundreds of such systems today managing diseases as standalone or web-based or mobile application in which Typhoid Fever is not left out. Typhoid Fever has been identified as one of the major killers and common diseases which kill more than the dreaded Acquired Immune Deficiency Syndrome (AIDS). Though drugs are available for the treatment of Typhoid Fever as against the dreaded (AIDS) but the large number of deaths are as a result of poor or misdiagnosis or no diagnosis at all as a result of shortage of medical expert, hospitals and equipment among others. It is good to use IT in medicine but the practice must be done with care. It was observed in this work that some of the available computer aided diagnostic systems on Typhoid Fever are mere software development exercise without any consultation with medical experts, strong diagnosis background and deployment of computational tools or predictive algorithms. Six basic stages or elements that can make a diagnostic system reliable were suggested in this work for researchers working in the area of developing Computer Aided Diagnostic and Therapy Systems.

General Terms
Diagnosis

Keywords
Diagnosis, Therapy, Typhoid Fever, Symptoms, Computational Methods

1. INTRODUCTION
Typhoid fever remains a major public health problem in developing countries of the world even in the twenty first century. Unacceptable morbidity and mortality are still recorded in developing countries inspite of the availability of several drugs over the years for the treatment of typhoid fever [13]. Typhoid fever also has both social and economic impact because of hospitalization of patients [5]. Prevalence of Typhoid fever in developing countries constitutes a major threat to the existence of humans due to inaccurate and untimely diagnosis procedures employed by medical practitioners in the region. In most parts of the tropics, the diagnosis of typhoid fever is based on smear microscopy and widal test, while in rare cases, it includes bacterial culture. However in rural settings of Africa, clinical diagnosis (based on symptoms) remains the only option for typhoid fever and this makes accurate diagnosis unlikely. Consequently, it is of concern that poor diagnosis continues to hinder effective control of Typhoid fever in the tropics [10].

The medical field needs appropriate facilities and medical experts for efficient service delivery. Deaths occur mostly in situations where patients conditions are critical and yet no medical facilities and experts to handle situations [1]. Because medications are readily available without a prescription, people with self-diagnosed infections can access treatments without first seeking a formal clinical consultation and/or laboratory confirmed diagnosis [14]. A bacterial called salmonella typhi (*s.typhi)* is responsible for typhoid fever. S.typhi may be spread by consuming contaminated water, beverages and food, after which the bacteria enter the intestines and then the bloodstream, where they may spread to other body parts [15]. Typhoid fever has a global presence, over 17 million people affected annually by typhoid fever and 600,000 succumb to it [12]. Medical diagnosis is a categorization task that allows physicians to make predication about features of clinical situations and to determine appropriate cause of action. It is a complex decision process that involves a lot of vagueness and uncertainty management, especially when the disease has multiple symptoms [8]. Therapy is the attempted remediation of a health problem, usually following a diagnosis. In medical field, it is synonymous with the word ("treatment") [7, 4]

Artificial Intelligence is a part of Computer Science that tries to make computers more intelligent. Computer Aided Decision Support System (DSS) that can simulate expert human reasoning or serve as assistant of physicians in the medical domain is increasingly important. In medical domains diagnostic, classification and treatment are the main task for a physician. System developed with such purposes is also a popular area in Artificial Intelligence (AI) research. Today, Clinical Decision Support System (DSS) are developed to act multipurpose and are combined with more than one AI method and Technique [7]. World Health Organization (WHO) estimates that African region has a shortfall of 817,992 health workers. Sub-Saharan African faces the greatest challenges with 11% of the world's population and 24% of the global burden of diseases; the region has only 3% of the world's health workers commanding less than 1% of world health expenditure. The ratio of available facilities to the teeming population is also grossly inadequate. These are among the major reasons why Information Technology (IT) has been employed over the years to help in different areas of healthcare [9].

In most tropical countries, most of which are developing countries, medical personnel and facilities are not adequate for effective tacking of tropical diseases. In rural areas,

medical attention is grossly inadequate. Intelligence systems have become vital in the growth and survival of healthcare sector. Recently much research efforts have been concentrated in designing intelligence systems [9].

2. REVIEW OF RELATED LITERATURE

Computer approach to diagnosis has witnessed unprecedented development in which typhoid fever is not an exceptional case. There are a number of computer based diagnosis assisted systems on typhoid fever today. Some of these works are presented below.

A Machine Learning Based Clinical Decision Support System for Diagnosis and Treatment of Typhoid Fever was developed by Oguntimilehin et al in [7]. This research was motivated by the following factors: Computer Aided System or Decision Support System (DSS) that can simulate expert human reasoning or serve as an assistant of a physician in the medical domain is increasingly important, in most tropical countries most of which are developing countries, medical personnel and facilities are not adequate for effective tackling of tropical diseases, earlier estimates of the global burden of typhoid fever indicate there are at least 16million new cases every year with 600,000 deaths. Research method: Two sets of data on typhoid fever cases were collected at different periods. First set was used as training set while the second set was used as testing set. C.45 Algorithm was used on the labeled training set to generate decision tree for the diagnosis. The tree was later converted to decision rules and these rules were implemented as the engine room of the diagnosis. Implementation was done using Visual Basic.NET as front end and MySQL as backend.

In the study of Omisoore et al [13], A Web Based Decision Support System Driven by Fuzzy Logic for the Diagnosis of Typhoid Fever, the motivations for the research include: research has identified Typhoid fever as the major cause of morbidity and mortality in most developing countries, to provide a decision support platform for medical practitioners, diagnosis of typhoid fever involves several variables which usually makes it difficult to arrive at accurate and timely diagnosis. The developed system made use of Fuzzy Logic for the diagnosis.

Oladipo et al in [16] presented a Mobile Compactable Expert System for the treatment of typhoid fever in developing countries. The motivations for this work include: Typhoid fever is rampant in developing nations with over 21.6 million cases and at least 250,000 deaths occurring annually, expert system developments today are either web based or stand-alone application. The methodology involved the use of object oriented programming approach. The application framework has three parts – user interface, application logic (written in PHP programming language) and Database component using Mysql server. No evidence of consultation with medical experts, data collection and usage. The prior knowledge and the basis for the diagnosis were not discussed. No computational methodology was deployed.

Adehor & Burrell in [3] presented the Integrated Management of Healthcare strategies and Differential Diagnosis by Expert System Technology: A Single Dimensional Approach. The motivations for this work include: Typhoid fever kills more people than the most dreaded Acquired Immune Deficiency Syndrome (AIDS), it kills one child every 30 seconds in the world. The methodology involved knowledge acquisition and elicitation using questionnaires and interview technique. The knowledge gathered were analyzed and represented in the form of Mockler Situation Analysis Methodology. Rapid prototyping using a simple expert system shell was used to develop the system due to its simplicity and fast learning curve. The situation was later analyzed and results were later converted to decision tables and finally rule sets, after discussion with medical consultants. The disease building blocks have 8 signs or symptoms it was a standalone system.

In [6], Oguntimilehin et al 2013 used a machine learning technique to carry out clinical diagnosis of typhoid fever. The motivations for this work are: Medical knowledge is today expanding rapidly making computer-aided diagnosis system desirable, machine learning technology is correctly well suited for analyzing data, and in particular there is a lot of work done in medical diagnosis in small specialized diagnostic problems, 17million cases of typhoid fever and 600,000 associated deaths occur annually. Method used: Data on typhoid fever cases were collected from reputable hospitals from Ekiti State, Nigeria. Medical experts classified typhoid fever cases into five different level of severity based on available symptoms. 100 data sets were used as training set; while another 50 data sets were used as testing set. A machine learning technique – Rough set was used to train the system and a total of eighteen (18) rules were generated during the training phase. These rules were used as the engine of the developed diagnostic system. 18 conditional attributes and one decision attribute were involved in the work. The detection rate of the system was later measured.

In the research carried out by vassal et al in [17], solution trees were employed to diagnose salmonellosis, botulism, hepatite, leptospirosis, typhoid fever and dysentery. Complaints, objective data and laboratory checkup were used in the solution trees formation. The tree was constructed on the basis of experts' collective evaluations with the usage of paired comparisons method. Algebraic methods of experts' information processing were used for the formation of an "effective" tree. The algorithm of consecutive analysis of variants was used for the determination of optional ways in solution trees that allows elaborating trees with thousands of peaks. This research was motivated because one of the first applied area of artificial intelligence methods usage was medical diagnosis, elaboration of expert systems in diseases diagnostic is more than 50 years, and as it is repeatedly noticed in the history of artificial intelligence, one of the main difficulties of artificial intelligence system elaboration is the "extraction" of knowledge from the specialist. The task is becoming more complicated if not a "fixed" but a "dynamic" knowledge is needed "way of thinking".

Quantum Associative Memory for the Diagnosis of some Tropical Diseases was presented in [18]. Four different diseases were diagnosed in this work – malaria, typhoid fever, yellow fever and dengue fever. The authors affirmed that most of the time, there is a misdiagnosis because of confusion between symptoms of malaria and symptoms of other tropical diseases like typhoid fever, yellow fever and dengue or the inexperience of the physicians. In this research work, diagnosis was carried out using Improve Quantum Associative Memory with Distributed Query. The database consists of 23 symptoms for malaria, 16 for typhoid fever and dengue and 10 for yellow fever.

In A Mathematical Model for the Transmission and Control of Malaria and Typhoid Fever by Adeboye and Haruna [19], the research was motivated by the following reasons: co-infection of malaria and typhoid has become a major public health concern in developing countries like Nigeria, Ghana, Mali and

Kenya, the higher the number of people affected by the two diseases, the higher the man – hour loss and this affects the economy negatively, as a result of poor diagnosis of typhoid due to similar signs and symptoms with malaria resulting in improper treatment and care which constitutes the major obstacle in managing the co-infection of the two diseases by health worker. The method used involved development of a model for malaria and Typhoid co-infection. The model (SIRS) is a system of eight (8) ordinary differential equations (ode). The first five (5) odes are for humans: susceptible S, Malaria infectious humans l_1, Typhoid-infections humans l_2, Malaria and typhoid co-infected humans I_3, and the Recovered humans sub-population R. The next two (2) are for mosquitoes: Non carrier mosquitoes M and infections mosquitoes N subpopulations: The last one is for *salmonella typhi* Bacteria B. All these were used in the mathematical models that led to the diagnosis of co-infection of malaria and typhoid fever.

A Rule Based Expert System for Diagnosis of Fever was developed by Sunday et al in [11]. The research motivations include: The two most common forms of fever in Nigeria are malaria and typhoid fever, malaria causes significant morbidity and mortality worldwide, in developing nations, scarce resources lead to inadequate diagnostic procedures. The method used in this work involved the development of expert system based on data collection and interaction with medical expert. The basis used for the generation of rules was not clearly stated. The rules used for the diagnosis were not mentioned. Performance evaluation of the system was not carried out.

Samuel and Omisoore in [10], presented a Hybrid Intelligent System for the Diagnosis of Typhoid Fever. The motivations for this work include: Prevalence of Typhoid fever (TF) on developing countries constitutes a major threat to the existence of humans due to inaccurate and untimely diagnosis procedures employed by medical practioners in the region, poor diagnosis continues to hinder effective control of typhoid fever in the tropics. Neural Networks and Fuzzy Logic were used to develop the hybrid system used for the diagnosis. The implementation of the system was achieved with Matrix Laboratory (MATLAB) version 7.9.0.529 which served as the core programming tool, Microsoft Access 2007 version which served as the database for medical records, Microsoft Excel 2007 version which was used to preprocess the required dataset into a format that could be exported to MATLAB workspace. The performance of the system was also evaluated.

Diagnosis and Recommender System for some Neglected Tropical Diseases was developed by Oluwagbemi and Oladunni in [21]. This research motivations include: failure to promptly diagnose and treat some tropical diseases such as chicken pox, cholera and typhoid fever is affecting the community – based management of such diseases, the high mortality rates caused by these diseases make the request for effective diagnosis and appropriate treatment an essential task. The developed system was based on the client/server architecture, structured as a 3 tier application. This system seems an expert system but no any solid background for the diagnosis, no a clear computational method(s) was employed as the basis for the diagnosis.

Genetic Neuro-Fuzzy System for the Diagnosis of Typhoid Fever was developed by Samuel and Omisore in [20]. This research was motivated by reasons which include: Typhoid Fever (TF) has constituted a major threat to the existence of human in most developing countries due to inaccurate and untimely diagnosis procedures employed by medical practitioners in the region, poor diagnosis continues to hinder efficient management of TF in the tropics. This research proposed an intelligent system driven by Genetic Algorithm, Neural Network and Fuzzy logic concepts for the diagnosis of TF. Evaluation of the developed system was also carried out.

Xpertmaltyph: An Expert System for Medical Diagnosis of the Complications of Malaria and Typhoid was developed by Fatumo et al in [15]. This research was motivated by the dearth of medical experts in the developing world which has subjected a large percentage of its populace to preventable ailments and deaths, the few medical experts always opt to practice in the urban cities. The formal model of the system was developed using unified modeling language (UML) so as to have a detailed description of the functionality of the system and understand the basic requirements. Java Expert system shell (JESS) was used to implement the expert module of the medical diagnosis system. No evaluation of the system's performance and clear rule generation.

Adehor and Burrell in [2], presented An Intelligent Decision Support System for the prompt diagnosis of malaria and typhoid in the malaria belt of Africa. The motivations for this work include: current diagnostic tools are affected by the harsh tropical weather, lack of qualified laboratory technicians, lack of regular supply of electricity to preserve diagnostic tools, lack of adequate transport facilities to move patents from rural to urban areas and a child dies every 15 seconds from water related diseases in which typhoid fever is one. Methodology: A study was carried out which confirmed that both typhoid fever and could be diagnosed based on signs and symptoms. A simplistic differential diagnostic model for the diagnosis of malaria, typhoid fever and unknown fever was formulated. The knowledge analysis of the system was carried out using Mockler Situation Analysis Methodology, the result of which has building blocks. The system was developed using rapid prototyping with a simple expert system shell. The system has a total of 53 rules in its knowledge base. The performance of the system was also evaluated.

3. SUMMARY OF THE FINDINGS FROM THE REVIEW

The review shows that a number of computer aided diagnostic tools/systems are available today on the diagnosis and treatment of typhoid fever. Some of these works focused symptomatic diagnosis method – a method of carrying out diagnosis based on available symptoms, while very few combined symptoms with laboratory results. Though symptomatic diagnosis was evident in medicine but needs to be done with caution. Observed motivations for most of the Computer Aided diagnostic tools include: shortages of medical experts, hospitals, diagnosis equipment. Others include: poor diagnosis, misinterpretation of laboratory results, large deaths as a result of poor diagnosis or misdiagnosis or no means of diagnosis, self-medication and drug abuse. All of these motivations are justifiable. Table 1 below shows the summary of the review at a glance.

Table1: Tabular view of the reviewed works on Computer Aided Diagnostic Systems for Typhoid Fever.

Researcher(s)	Year	Motivation(s)	Method Used
Oguntimilehin et al [7]	2014	- In most developing countries medical personnel and facilities are not adequate. - 16 millions of new cases of typhoid fever with over 600,000 deaths yearly.	Decision tree
Samuel et al [13]	2013	- Typhoid fever is the major cause of morbidity and mortality in most developing countries. - Typhoid fever involves several variables which usually makes it difficult to arrive accurate and timely diagnosis.	Fuzzy logic
Oladipo et al [16]	2014	- Typhoid fever is rampant in developing nations with over 21.6 million cases and at least 250,000 deaths occurring annually. - Expert system development today are either web based or standalone system.	Expert system with three parts – user interface, Application logic and database component
Adehor and Burrell [3]	2008	- Typhoid fever kills more people than the most dreaded Acquired Immune Deficiency Syndrome (AIDS). - Kills one child every 30 seconds in the world.	Knowledge Analysis and Representation using Mockler-Situation Analysis, Rapid Proto-typing Using Expert System
Oguntimilehin et al [6]	2013	- Medical knowledge today is expanding rapidly making computer – aided diagnostic system desirable. - 17 million cases of typhoid fever and 600,000 associated deaths occur annually.	Rough Set
Vasal et al [17]	2008	- One of the first applied areas of artificial intelligence methods usage was medical diagnosis. - Elaboration of expert systems in diseases diagnostic is more than 50 years. - One of the main difficulties of the artificial intelligence system elaboration is the "extraction" of knowledge from the specialist.	Solution Trees
Njafa et al [18]	2013	- Most of time, there is a misdiagnosis because of confusion between symptoms of malaria and symptoms of other tropical diseases like typhoid fever, yellow fever and dengue or the inexperience of the physicians.	Improve Quantum Associative memory with Distributed Query.
Adeboye and Haruna [19]	2015	- Co-infection of malaria and typhoid has become a major public health concern in developing countries like Nigeria, Ghana, Mali and Kenya. - The higher the number of people affected by the two diseases, the higher the man-hour loss and this affects economy negatively. - Poor diagnosis of typhoid and malaria.	A mathematical model (SIRS) with eight (8) ordinary differential equations (ode)
Sunday et al [11]	2013	- The two most common forms of fever in Nigeria are malaria and typhoid fever. - Scarce resources lead to inadequate	Expert system development methodology.

		diagnostic procedures.	
Samuel and Omisore [10]	2013	- Prevalence of typhoid fever (TF) in developing countries constitutes a major threat to the existence of humans due to inaccurate and untimely diagnosis procedures employed by medical practitioners in the region. - Poor diagnosis continues to hinder effective control of typhoid fever.	Neural Network and Fuzzy Logic
Oluwagbemi and Oladunni [21]	2010	- Failure to promptly diagnosis and treat some tropical diseases such as chicken pox, cholera and typhoid fever is affecting community based management of such diseases. - High mortality rates caused by these diseases.	Expert system with client/server architecture, structured as a 3 – tier application.
Samuel and Omisore [20]	2013	- Typhoid fever (TF) has constituted a major threat to the existence f human in most developing countries. - Poor diagnosis continues to hinder efficient management of typhoid fever in the tropics.	Genetic Algorithm, Neural-Network and Fuzzy Logic
Fatumo et al [15]	2013	- Dearth of medical experts in the developing world which has subjected a large percentage to its populace to preventable ailments and deaths. - The few medical experts always opt to practice in the urban cities.	Formal model of the system was developed with Unified Modeling Language (UML). Java Expert System Shell (JESS) was used for the implementation.
Adehor and Burrell [2]	2008	- current diagnostic tools are affected by the harsh tropical weather - lack of qualified laboratory technicians, lack of regular supply of electricity to preserve diagnostic tools - lack of adequate transport facilities to move patents from rural to urban areas and - a child dies every 15 seconds from water related diseases in which typhoid fever is one	Knowledge Analysis and Representation using Mockler-Situation Analysis, Rapid Proto-typing with simple Expert System shell.

4. CONCLUSION

The study shows that Typhoid Fever is prevalent in developing countries and is associated with huge number of deaths. Shortages of medical experts, hospitals and equipment are some of the major problems confronting the health sector of most developing countries and thus responsible for misdiagnosis, poor diagnosis, self-medication, drug abuse, deaths and economic backwardness. It was also evident that the computer technology has been successfully utilized in the health sector in conjunction with medical experts to develop computer aided diagnostic systems. However it is observed that some of these systems failed in their bid to meet up to expectation. Some developed diagnostic systems without therapy. Lack of clear computational methodology for diagnosis, lack of consultation with medical experts, lack of evaluation of the performance of the system are other problems confronting most of the Computer Aided Diagnostic systems. Computer experts working in the field of diagnosis and therapy should note that nothing could be achieved without consultation with medical experts. Some of these systems are mere software development exercise without any strong diagnosis background or computational method employed. It is suggested in this work that researchers working in the area of medical diagnosis should examine if the developed system satisfy the following facts/steps among others. If any of the steps mentioned below is lacking, such a system may not be desirable to be used in the health sector.

(i) Problem Definition & Literature Review

(ii) Consultation with medical experts

(iii) Real life data collection, observation of medical doctor diagnosed cases on the disease under consideration

(iv) Deployment of computational methods for diagnosis e.g. statistical, mathematical models, machine learning etc.

(v) Rules generation or rules extraction from (iv) above

(vi) Performance Evaluation of the developed system based on real life data.

Accessibility of the systems could be improved by making them web-based or mobile based.

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