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The Integrated Management of Health Care Strategies and Differential Diagnosis by Expert System Technology: A Single-Dimensional Approach

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***Abstract*—**The Integrated Management of Child illnesses (IMCI) and the surveillance Health Information Systems (HIS) are related strategies that are designed to manage child illnesses and community practices of diseases. However, both strategies do not function well together because of classification incompatibilities and, as such, are difficult to use by health care personnel in rural areas where a majority of people lack the basic knowledge of interpreting disease classification from these methods.

This paper discusses a single approach on how a stand-alone expert system can be used as a prompt diagnostic tool for all cases of illnesses presented. The system combines the action-oriented IMCI and the disease-oriented HIS approaches to diagnose malaria and typhoid fever in the rural areas of the Niger-delta region.

***Keywords*—**Differential diagnosis, Health Information System (HIS), Integrated Management of Child Illnesses (IMCI), Malaria and Typhoid fever.

I. Introduction

THIS paper discusses the process of developing and implementing an expert system to diagnose malaria and typhoid fever, and how the system can be used as the interface for the differences in the terms used in the classification of diseases in the Integrated Management of Childhood Illness (IMCI) and the disease surveillance Health Information System (HIS) [1]. The chosen area for this research was the rural areas of the Niger Delta Region of Nigeria, West Africa.

Malaria is endemic in the Niger Delta region of Nigeria and the disease kills one child every 30 seconds in the world [2], [3]. The fact that the disease kills more people than the most dreaded Acquired Immune Deficiency Syndrome (AIDS), is not because it is not curable, but because the disease has signs that are very similar to those of other notable febrile illnesses in the region of which typhoid fever, a water borne disease, is eminent [4], [5].

Thus, even though diagnosing malaria based on signs and symptoms is justifiable [1], [6]; its management by health care personnel in the rural areas has become ever more complicated because of its overlapping symptoms and signs with those of other febrile diseases in the region.

The use of signs and symptoms for the diagnosis of malaria and typhoid fever does not mean to say that other diagnostic tools are unavailable. The problem here is that these tools are either affected by the harsh tropical weather or there are no qualified medical personnel in the rural areas to interpret test results. Above all, the lack of regular, or no supply of electricity to store available microbiological chemicals, for the prompt diagnosis of the disease, is a great setback.

The worst affected age groups are children aged between 1 week and 5 years. The IMCI was initiated to manage child illnesses in order to save lives but this differs in approach from HIS which basically monitors epidemics of a disease outbreak in a particular region. This difference in approach in disease classification can cause confusion [1].

Our system carries out its disease diagnosis based on signs and symptoms, but places great emphasis on the fact that medicine is evidence based. This is done using differential diagnosis by asking questions in two formats, one directed at the user, while the other is directed at the patient. The questions directed at the user emphasizes the role of medicine that is evidence based (i.e. the user is given the opportunity to critically observe the patient).

The expert system has the advantage of not allowing users to input wrong signs or symptoms, as researched by Bojang et al, [7]; [8]; [9], using algorithms and computers to diagnose malaria. Another great advantage of this system, compared to other information systems [10], is the fact that it is a stand-alone system that does not rely heavily on electricity or an information technology infrastructure. It is intended to be mounted on the One Laptop Per Child computer that would be powered by a wind-up crank or solar panel [11], or any desktop computer or a Hand Held device.

The system takes into consideration the fact that IMCI is an age (i.e. between 1 week and 5 years) related strategy for the management of child illnesses. This same principle can be used with children with an age greater than 5 years as well as adults and thus, by providing this differential approach to diagnosis, would make the system a good candidate for managing diseases in community practices as a whole. According to the HIS classification, disease prevalence in children greater than 5 years or adults; is a good indication of a disease epidemic. A major objective of this system was to provide a simplistic approach to diagnosis, based on the fact

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that people with 4-5 years of education, in the south eastern part of Nigeria, can actually diagnose malaria [12].

II. Methods and Findings

Our study was based on the Niger-delta region of Nigeria, in West Africa, where malaria and typhoid fever are known to be prevalent [3], [5]. This research was approached with the aim of ascertaining whether the diseases could be diagnosed based on signs and symptoms in the region.

The results of our survey findings showed that 60% of physicians agreed to the fact that both diseases could be diagnosed differentially based on signs and symptoms. Also, the results of the survey questions suggested that the system could also be used as the interface to resolve the problem of the disease classification issues that are associated with IMCI and HIS. We interviewed five consultants at the University of Portharcourt, teaching hospital Rivers State and the Federal Ministry of Health, Asaba Delta State in Nigeria respectively in order to ascertain the building blocks upon which febrile diseases can be differentially diagnosed. The outcome of the interview is shown in Fig. 1. The building blocks indicate the signs and symptoms during a consultation.

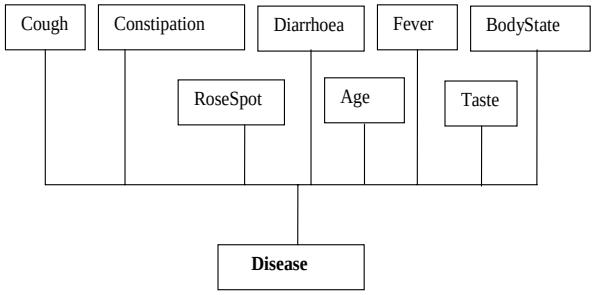


Fig. 1 Block diagram for the febrile diseases

III. Action and Disease Oriented Differential Diagnosis of Malaria and Typhoid Fever

The IMCI strategy is a set of standard clinical guidelines that covers children aged from 1 week to 5 years for the management of sick children who are brought to a health facility. This strategy is based on simple clinical signs without relaying on laboratory test. This strategy also includes other interventions relating to the health system as a way of looking for ways to improve family and community practices [1]. One of the greatest challenges has been to make the IMCI an action-oriented classification at a primary health care level, compatible with the disease-oriented HIS classification.

A good example to illustrate this fact is to pick one of the diseases classified in IMCI as being associated with fever e.g. “disease with fever”. IMCI could classify this condition as “very severe febrile disease”; whereas HIS could classify it as “dengue fever”. This type of classification can confuse health care workers with little practice in diagnosing illnesses. Another notable issue identified with IMCI usage is that it could classify children with fever as malaria even though the cause of fever is typhoid fever, respiratory infection or diarrhoea. This is of particular concern in countries with endemic malaria such as the Niger-delta region of Nigeria. There is also the problem of incompatibility with the way age is recorded in both IMCI and HIS respectively, which can confuse healthcare personnel in situations where both strategies are being used. Fig. 2 is a simple differential diagnostic model for malaria, typhoid fever and unknown-fever (i.e. unknown-fever could be any other febrile illnesses, e.g. pneumonia, meningitis or diarrheoa to mention but a few).

A lot of resources have been directed towards finding out strategies to link the IMCI and the health information system classifications. Results have shown that none of these are actually cost effective, as staff would have to spend time translating the IMCI classification into HIS classification or vis-visa by using a standardization Table I.

This simple, stand-alone expert system can overcome some of these difficulties by differentially diagnosing febrile illnesses based on signs as well as age differences in the range 1 week to 5 years, age greater than 5 years, or adults. This is achieved by incorporating surveillance factors such as travel history and season of the year as part of the diagnostic strategy.

This system would be suitable for people in the rural areas of the Niger-delta region where febrile illnesses are misdiagnosed due to the complication of interpreting the IMCI chart.

However, because the system can diagnose diseases for patients greater than 5 years and adults, results can be recorded and reported to HIS to help detect epidemics in cases of community health practices.

The system works on the simple fact that medicine is evidence based and can be used by people with 4 -5 years of education with little training and, as such can also be used in the home management of the diseases [13], due to its portability and learner ability.

IV. Knowledge Engineering

The knowledge acquisition and elicitation stages of the system were achieved using questionnaires and interview techniques. The knowledge gathered from these processes were analysed and represented in the form of the Mockler Situation Analysis methodology [14]. 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 analyzed, based on the assumption that IMCI is action-oriented and HIS is disease-oriented. This in turn provided the intended goals and subsequently, the actions or methods to achieve these goals. In Artificial intelligence this is referred to as backward chaining, as this enables the system to prove one particular hypothesis at a time before moving on to another hypothesis [15].

The results from the initial analysis were discussed explicitly with the consultants and after further revisions, converted into decision tables which, in turn, made up the rule sets that provided the decision support for the IMCI strategy. Questions supporting the action-oriented strategy were asked in two formats, 1. The first question is directed at the user of the system to enable him or her to observe the patient, 2. The second question is directed at the patient or child’s custodian to find out his/her condition.

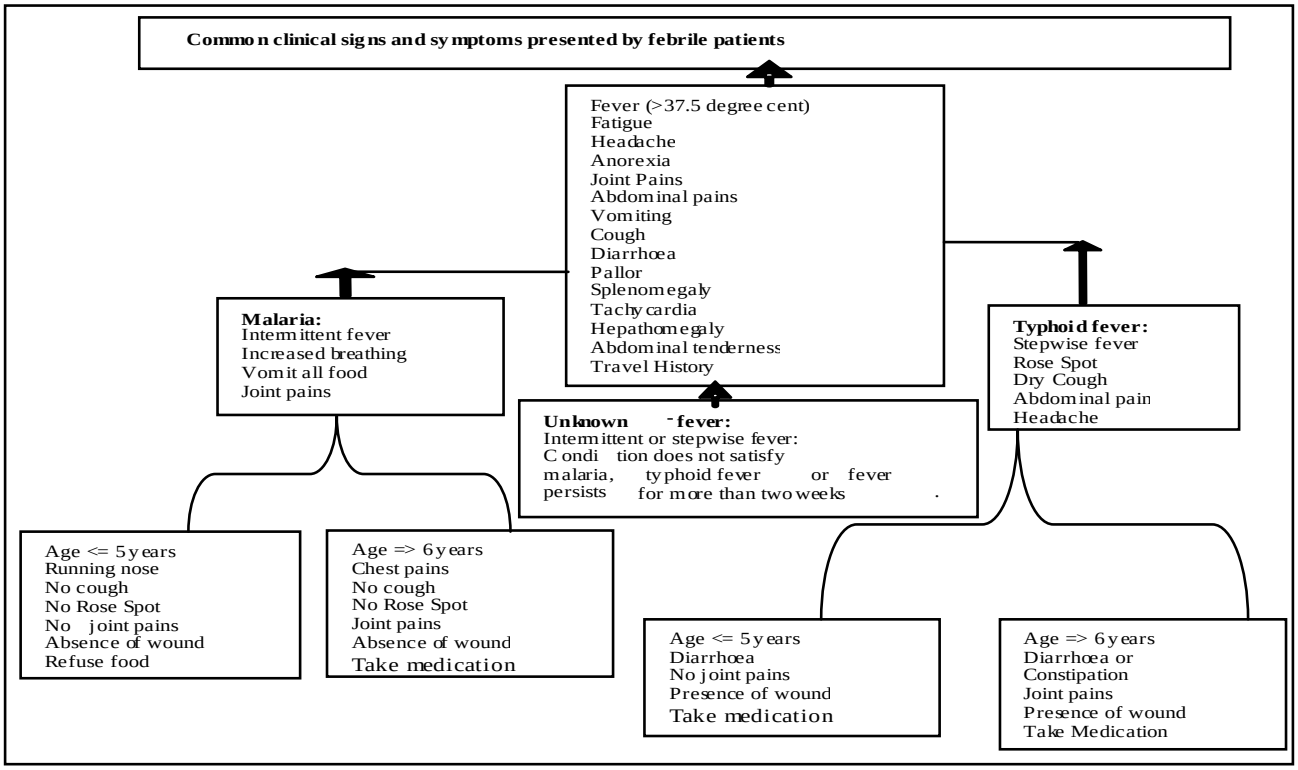


Fig. 2 A simple differential diagnosis of malaria and typhoid fever

As with any diagnostic decision support tool, the lines of reasoning are based upon supporting evidence which, in most cases, is less than certain [16]. This uncertainty was added to the decision tables and subsequently incorporated into the rules in the form of certainty factors on a scale of 0-100. This initial uncertainty, in each line of reasoning, was provided by the consultants. This implies that for every disease that is diagnosed, a certainty factor is generated as to the probability of the consultation being correct. This compares favorably with the overall reference standard supplied by the consultants (Fig. 5).

The disease building blocks have 8 signs or symptoms (i.e. cough, bodystate, constipation, age, diarrheoa, fever, rosespot and taste), which have to be confirmed to be true or false in order to progress to the disease-oriented stage (HIS). During consultation with the system, a series a questions were asked in a common sense fashion in order to prove that the patient actually had a particular identified sign or symptom. For example to prove that a patient had cough or diarrhea a set of 3 or 4 questions were asked in different combinations depending on the patient's prevailing condition and age. Thus, questions are asked that are relevant to a particular hypothesis [15]. The system can also give explanations as to why a particular question is asked as well as how it arrived at the diagnosis of the disease and how certain it is regarding the diagnosis (Fig. 4).

V. IMCI/HIS Expert System Interface Architecture

The general architecture of the expert system is shown in Fig. 3, where it can be seen that the rules that form the action-oriented strategy of IMCI are analyzed and stored in the knowledge-base of the system. The system commences the diagnosis with the patient's age and then interrogates the patient for fever, cough, taste, bodystate, rosespot, diarrheoa and constipation.

The system takes into consideration cases where a particular sign might be caused as a result of medication or the patient's travel history. A typical consultation is shown in Fig. 4 where different questions are asked in different combination to prove or disapprove a rule set. Depending on the patient and user's response to questions; the system generates the next question. Hence, all approved rule-sets then combine differentially to reach a decision (i.e. disease-oriented state) as to the disease diagnosed with certainty factor. The disease certainty factor can be recorded for use in HIS.

VI. System Evaluation

According to WHO/UNICEF, several options exist for resolving the IMCI-HIS incompatibilities and these include: 1. translating IMCI classifications into HIS classifications;

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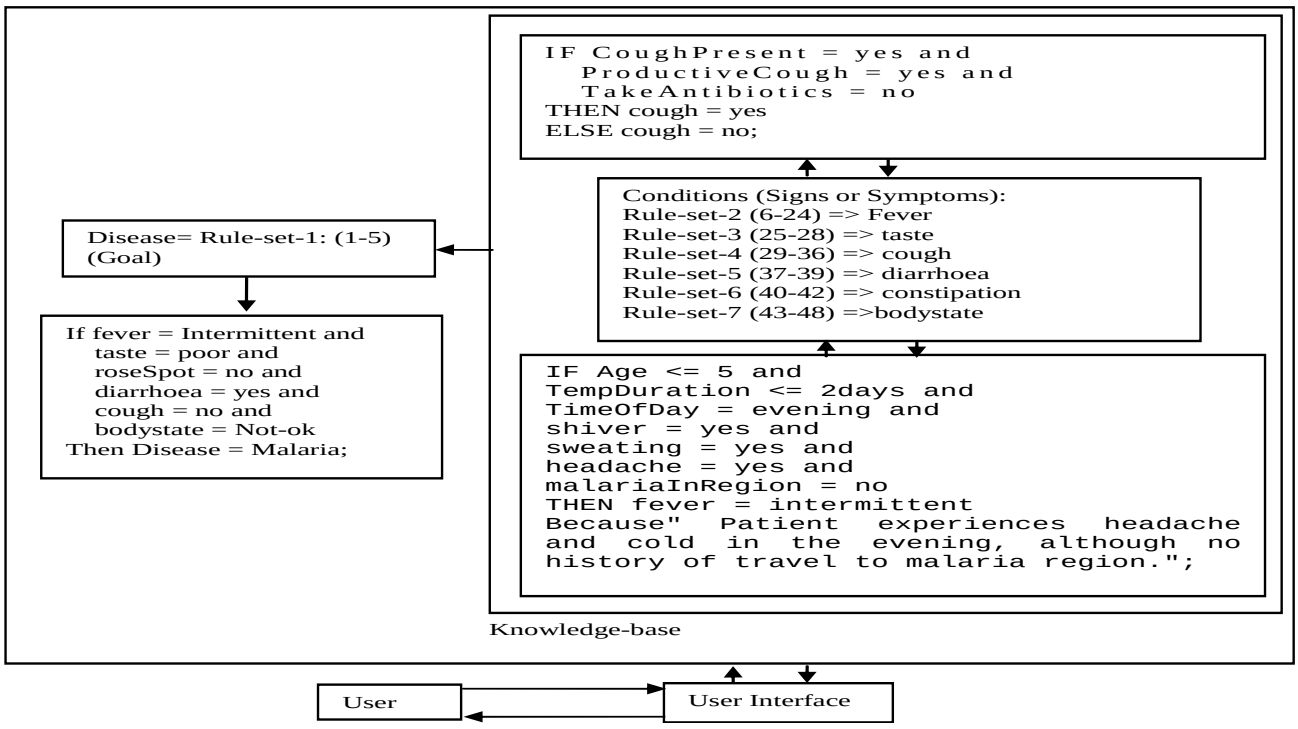


Fig. 3 General Expert System Architecture

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2: changing the HIS list to include IMCI classifications; 3: using both IMCI and HIS classification systems at the time of consultation; and 4:.doing nothing [1]. A view supported by the consultants who tested the system confirmed that a simple expert system that can be used to promptly diagnose malaria and typhoid fever differentially based on signs and symptoms can also be used as an interface to resolve the problems associated with IMCI and HIS integration. It was also recommended that the system should incorporate other diseases like pneumonia, meningitis and diarrheoa.

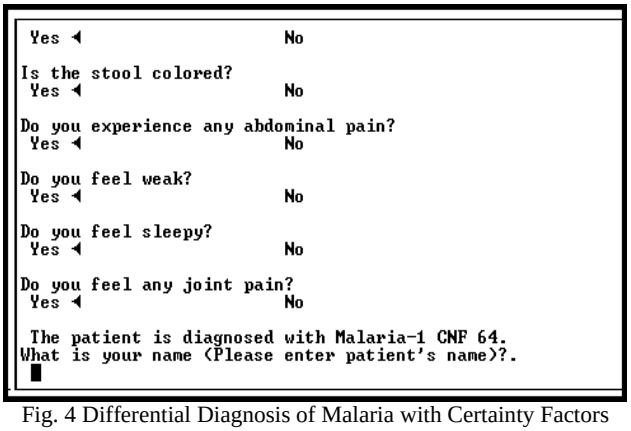


Fig. 4 Differential Diagnosis of Malaria with Certainty Factors

The greatest advantage of this system is its simplicity of use and the intelligent way in which it responds to user's answers to questions in order to generate the next question in a simple common sense manner. It eliminates the issue of entering wrong data during consultation and does not require any complex infrastructure like some existing systems [10]. The system acts as an interface between IMCI and HIS by its ability to incorporate the action-oriented strategy of IMCI in its knowledge-base and then interpreting the results in accordance with disease-oriented approach of HIS (fig. 3). Thus, the system would be useful in the rural areas and eliminate the difficulty associated with translating the IMCI-HIS incompatibilities by rural health care personnel. It would also save the cost of additional time required to translate these results. Rather than 'do nothing' as stated in one of the options of resolving the IMCI-HIS incompatibilities, this system generates certainty factors that are comparable to physicians diagnostic results based on the prevalence of the disease in the region as shown in Fig. 5.

The system can be used for the prompt diagnosis of malaria and typhoid fever. Malaria and typhoid fever are diseases that are most prevalent in the Niger-delta region and are used to demonstrate how diseases, that are classified as severe fever by IMCI strategy, can be resolved by the system to specie specific diseases that can be used to predict the degree of occurrence based on the patient age and travel history.

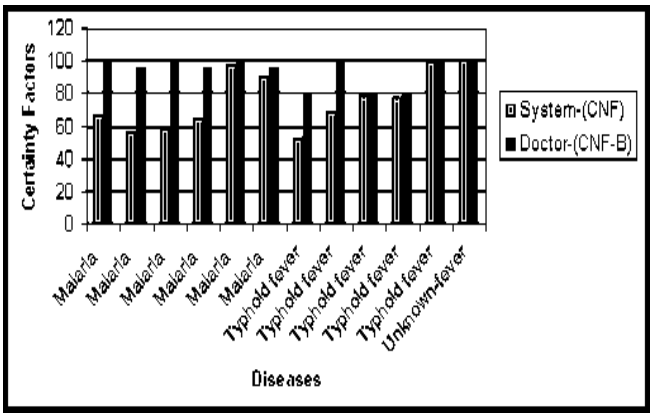


Fig. 5 System diagnoses as compared to Physicians' reference standard

The system diagnosed two specie of malaria and two of typhoid fever and the results of the diagnoses are shown in fig. 5. The interpretation, put forward by physicians, was that as the sign of a disease in a region becomes more specific the positive predictive value (i.e. certainty factor CNF) of the system increases to match those of physicians. The present system is a stand-alone application using human judgment and intelligent decision support techniques which provide efficient search strategies to interrogate the knowledge base [17]. For example, typhoid fever has signs that are very similar to malaria and has some symptoms of diarrheoa. These are very different from diarrheoa, as a disease classified by the IMCI strategy.

According to Rafael et al [18], new diagnostics test should require minimal infrastructure and not rely on electricity or water and that training in differential diagnosis should be provided to health care personnel in the rural areas. Thus, in a later incarnation of the system other diseases like diarrheoa, meningitis and pneumonia will be incorporated, as advised by the physicians who tested the system. This would greatly enhance its usefulness as a differential diagnostic tool as well as an interface between IMCI and HIS in the rural areas that lack the manpower, understanding and resources.

VII. Recommendations and Conclusion

The system, as reported in this paper, clearly demonstrates the viability of developing an expert system which uses simple observations as a means to diagnosing malaria and typhoid fever. It is mounted on a laptop (e.g. the One Laptop Per Child computer powered by a wind-up crank) as a stand-alone application.

The importance of the system can not be overemphasized as the consultants who tested the system recommended it should incorporate other febrile diseases. Thus, rather than do nothing regarding the IMCI-HIS classification issues, the portability and simplicity of the system makes it a suitable tool to be used as an interface for the IMCI-HIS disease management and monitoring strategies in the rural areas.

This system would help to reduce child mortality rates in the rural areas where there are no ready diagnostic tools or few skilled medical personnel to make use of sophisticated tools that would also require a constant power supply. Another vital

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area that the system could be put into use for is in the area of gathering statistics based on its ability to actually predict the certainty of the disease as compared to those of other diseases in the region.

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