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Expert System Based on Rules and Medical Knowledge for the Medical Diagnosis of Typhoid Fever (XperTyph)

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Authors' contributions

This work was carried out in collaboration of between both authors. Authors ARNS and HCM in data collection, statistical analysis, decision table construction and all paper corrections. Both authors read and approved the final manuscript.

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ABSTRACT

Today, common diseases like malaria, typhoid, cholera and others are becoming more dangerous problems for people living in this world. It is simple to use, portable, inexpensive and makes the diagnosis of typhoid faster, more efficient and more accurate, and helps doctors avoid wasting time on the diagnosis of typhoid and the publication of results. The objective is to know how to avoid the queue of patients in the hospital. In this article, the author proposed a model of expert systems using the knowledge of physicians and other health professionals. The expert system Xper Typh is useful for patients who suffer from typhoid fever. This system will give a response similar to that of a doctor or a medical expert. This system is also very useful in rural areas where we have young medical experts or no medical experts. Study cross-sectional between the Cabinda Provincial Hospital and the Center 1st of May Health in Cabinda during June 2015 and July 2018. We included 65 patients (22 men, 28 women and 15 children); age group from 5 to 75 years old. The patients examined presented different symptoms and signs. On 65 patients, 20 patients with confirmed fever, 25 patients without confirmed fever and 20 contraction patients between the

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expert system and the physician. The results between the doctor and the expert system are as follows: Sixty-five patients were diagnosed with XpertTyph. The XpertTyph correctly identified 20/65 (30%) of patients with typhoid fever and 25/65 (41%) of patients not suffering from typhoid fever. That is 71% concordance and 29% discrepancy. The criterion of validity of the model presented the best content for a certain level of average diagnosis for the diagnosis (k = 0.21 to 0.40) for typhoid fever which corresponds to 69% of confidence.

Keywords: Diagnose; fever typhoid; decision table; expert system; XperTyph.

1. INTRODUCTION

Today, expert systems are used almost in all areas of human expertise to help users make decisions; where human expatriation and multi-faceted decision-making are needed, such as medical diagnosis, decision-making by an expert. Artificial intelligence in medicine is mainly concerned with the construction of artificial intelligent programs that allow for diagnosis and may also recommend treatment. Medical expert systems are more likely to be found in clinical laboratories and educational institutions, for clinical surveillance or in data-rich areas, such as intensive care facilities. What is happening is that if they do the right thing, smart programs offer significant benefits. The use of a System Expert in medicine has been in full swing since the early 1970s, when MYCIN was designed to diagnose bacteria that cause severe infections. There are many systems of medical experts such as the PUFF system, developed to diagnose lung diseases; ANGY helps doctors diagnose narrowing of coronary vessels by identifying and isolating coronary vessels in angiograms; BABY helps clinicians by monitoring patients in a neonatal intensive care unit. Expert systems can be classified in two; those based on rules, known as rule-based expert systems, and those based on probabilistic graphical models, often referred to as probabilistic expert systems or normative systems. Rule-based expert systems, derived from the work of Buchanan and Shortliffe on MYCIN, aim to capture human expertise in terms of form rules if condition, then action. There is irresistible evidence that this rule is capable of modeling the process of human thought. A set of rules can be used to capture knowledge of the relevant field of a human expert and can then be used to replicate the problem solving of the expert in this field. Probabilistic expert systems stem from research at the intersection of statistics and artificial intelligence [1,2].

Rule-based expert systems include both conventional techniques, such as database management systems, and artificial intelligence techniques, such as knowledge-based systems. database management are used to store, retrieve and generally manipulate patient data, while a Systems Expert is primarily used to perform diagnostics based on patients' symptoms, as they can represent in a natural way how experts reason and provide a solution [3].

In this research work, a rule-based expert system is used to diagnose the following diseases such as typhoid fever.

1.1 Diseases Considered

Diagnosing is one of the attributes of medical competence! The effort to explain the components of the diagnostic process is one of the key elements of the "diagnostic process". Based on these precepts, the researcher's praxis, the knowledge and experience of medical professors, both in medicine and in teaching, we proposed a study to evaluate the clinical reasoning (cognitive process) of these professionals, facing a real and typical clinical situation. The results may contribute to the teaching of clinical reasoning and diagnosis and be included in the learning of this and other medical specialties.

Typhoid Fever: Typhoid fever is a systemic disease caused by contaminated food or water and is caused by enteric Salmonella bacteria, and these bacteria are pathogenic only in humans. Paratyphoid is a similar disease Clinically, caused by Paratyphi A, B or C, enteric serovar of Salmonella and these conditions are sometimes collectively referred to as enteric fever [4].

Typhoid fever: Typhoid fever is a bacterial disease transmitted by the consumption of water or contaminated food. Typhoid fever is an infectious disease basically transmissible from man to man by direct contact with an infected person, or indirect by food consumption contaminated during their preparation by a sick person (or healthy carrier), or by consumption of food contaminated with water contaminated with feces, or by consumption of contaminated drinking water; like any transmission disease or fecal, typhoid fever occurs the most often in areas where hygiene is precarious [5].

In most low-income countries, typhoid fever is a major public health problem. Global estimates of the burden of typhoid fever vary between 11 and 21 million cases and about 128,000 to 161,000 deaths per year. The majority of cases occur in South and Southeast Asia and in sub-Saharan Africa. On the other hand, in developing countries, particularly in Africa, this pathology is still endemic. 16 to 33 million people have typhoid fever, with more than 200,000 to 500,000 deaths annually.

The statistical data show that more than 10,000 confirmed cases of blood cultures typhoid fever severe enough to require outpatient or hospital care showed that 27% of all cases occurred in the age group from 0 to 4 years old. In this age group, about 30% of cases in children under 2 years of age and 10% in infants aged < 1 year [6].

1.2 Symptoms

People with typhoid fever carry the bacteria in their bloodstream and intestinal tract. Symptoms include prolonged high fever, fatigue, headache, nausea, abdominal pain and constipation or diarrhea. Some patients may have a rash. Severe cases can lead to serious complications or even death. Typhoid fever can be confirmed by blood tests and lives only in humans.

1.3 Epidemiology, Risk Factors and Disease Burden

To improve living conditions and reduce morbidity, industrialized countries have introduced antibiotics. However, in developing regions of Africa, the Americas, South-East Asia and the Western Pacific, the disease remains a public health problem. The estimates that there are 11 to 20 million annual cases of typhoid fever worldwide, causing about 128,000 to 161,000 deaths a year. The risk of typhoid is higher in populations without access to safe water and adequate sanitation. Poor communities and vulnerable groups, including children, are most at risk [7].

1.4 Artificial Intelligence

According Russell and Norvig [8] intelligence can be defined as a science that has the ability to learn and understand, solve problems and make decisions. However, artificial intelligence is the display of intelligence by machines and its main purpose as a field is to make machines do things that would require intelligence as if they were done by humans.

The core issues of Artificial Intelligence include traits such as reasoning, knowledge, planning, learning, communication, perception, and the ability to move and manipulate objects. In the early 90s, Artificial Intelligence achieved its greatest achievements in practice despite all its previous setbacks.

It has been successfully applied in the fields of logistics, data extraction and medical diagnostics. However, the success of Artificial Intelligence has begun to recover with the commercial success of expert systems.

1.5 Expert Systems

An expert system is a computer program that uses knowledge of a problem specific to a given domain and emulates the methodology and performance of an expert in the field concerned. The knowledge inherent in an expert system is a key element of its construction and is usually defined by knowledge engineers or programmers. To this end, experts in the field of the problem are consulted and attempts are made to code in formal language all the knowledge acquired during their experience, including heuristics methods and tips. Expert systems do not reproduce the structure of the human mind or the mechanisms of intelligence. These are practical programs that use heuristic strategies developed by humans to solve specific problem classes. They constitute a class of programs in the field of artificial intelligence and have contributed to the success of this sector thanks to the developed commercial products. Expert System is a form of artificial intelligence program that simulates the knowledge and analytical skills of one or more human experts. Although a common strategy is to find only one expert, when a more complex expert system is under construction or when the expertise is not well defined, it may be necessary to use several experts conventional expert systems are designed for a very narrow field with clearly defined expertise. This makes the performance of the system entirely dependent on the good choice of experts [9].

GIDEO: Expert System was developed ten years ago by infectious disease specialists and computer scientists from academic medical schools in the United States and Israel. GIDEON is an expert diagnostic and reference system in the fields of tropical and infectious diseases, epidemiology, microbiology and antimicrobial chemotherapy. It has been designed to diagnose all infectious diseases of the world based on symptoms, laboratory tests and dermatological profile. It helps in the diagnosis of infectious diseases, but is difficult to maintain, manage and upgrade because it is not web-based. It also tries to diagnose all complicated infectious diseases.

GIDEON helps doctors when diagnosing, it generates a classified list of possible diseases based on signs, symptoms, laboratory tests and history of exposure to any infectious disease, in any country in the world.

Expert system used for infectious diseases difficult to identify in patients with travel history. It clarifies unusual patterns of illness and helps plan an effective treatment. It is a very useful resource for physicians as it provides support for the decision to generate a differential diagnosis [10].

MYCIN: MYCIN, an expert medical diagnostic system, developed in 1972 at Stanford University. Its purpose is to provide physicians with advice on the diagnosis and treatment of bacterial infections. It identifies the organisms responsible for an infection based on the patient's symptoms and test results. It was developed in LISP language for Edward Shortliffe in his doctoral thesis and under the direction of Bruce Buchanan, Stanley. Cohen and others. This expert system was designed to identify the bacteria that cause severe infections, such as bacteremia and meningitis, and to recommend antibiotics, the dosage being adapted to the weight of the patient. The name is derived from the antibiotics themselves, many antibiotics having the suffix "mycine" [11].

Fig. 1 shows the expert medical system diagram XperTyph is a medical expert system for diagnosing typhoid.

2. MATERIALS AND METHODS

The objective of this research was to develop an expert system, using expert software, to diagnose typhoid fever. The research is classified as qualitative, since it seeks to validate the system at the quality level of the answers (diagnosis) presented. The research was developed in the following steps:

Phase 1: Problem Identification

Our approach is to develop a decision support system for typhoid fever. In particular, we have designed this decision support system for rural or remote areas where experts are not available. This system makes diagnosis easier for the medical staff and even anyone makes a diagnosis by answering the question of the disease.

Phase 2: Knowledge Acquisition

We collected the information with the help of experts/doctors, and we refer to the appropriate books on mosquito diseases. Knowledge is a gain from the internet. Search for topics on mosquito disease using a search engine like google.

Phase 3: Knowledge Representation

There are more than 7 rules successfully generated by acquiring knowledge.

Phase 4: Verification and Validation

Rules designed for the disease using symptoms added to the knowledge base are correct. The whole symptom has always been checked to make sure that the correct symptom of a disease is correct. The base of the rules is designed with the consultation of the symptoms with the physician.

Table 1, showing the result obtained after receiving the completed questionnaire by physicians and health professionals divided into five groups, gave their opinion typhoid fever (MP).

Table 2 shows the result obtained after receiving the questionnaire completed by physicians and health professionals divided into five groups, they gave their opinion typhoid fever (Probable).

Table 3, shows the result obtained after receiving the completed questionnaire by physicians and health professionals divided into five groups, they gave their opinion typhoid fever (Little probable).

Table 4, shows the result obtained after receiving the completed questionnaire by physicians and health professionals divided into five groups, they gave their opinion typhoid fever (Not likely).

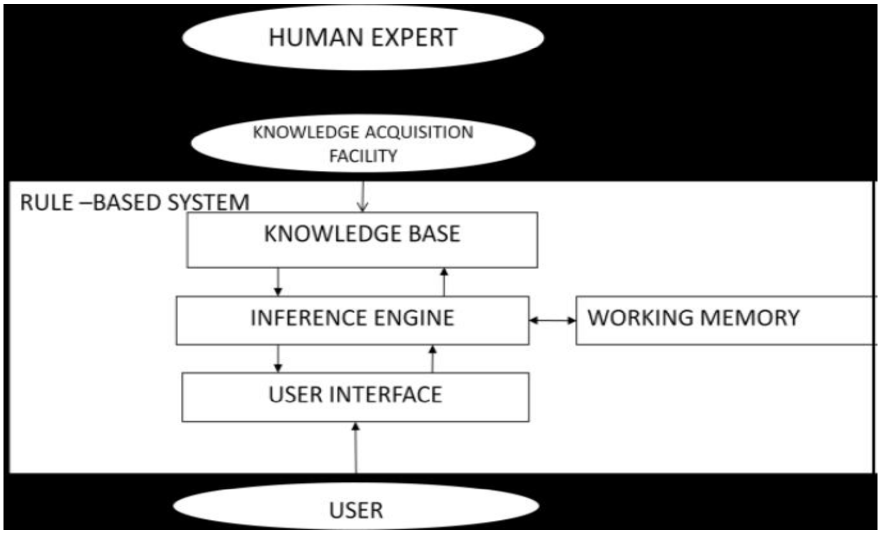

Fig. 1. Main components of expert systems

Table 1. Expert´s opinions of typhoid fever (more probable) Hospital Provincial of Cabinda

Typhoid Fever				
More probable				
1º Group	2º Group	3º Group	4º Group	5º Group
Acute fever	Acute fever	Acute fever	Acute fever	Acute fever
Constipation	Constipation	Abdominal cramps	Constipation	Constipation
Diarrhea	Diarrhea	Asthenia	Diarrhea	Diarrhea
Vomiting	Vomiting		Colica Abdominal	Colica Abdominal
Chills	Colica abdominal		headache	headache
Headache			Asthenia	Chills
Artrhalgia				Asthenia

Table 2. Expert´s opinions of typhoid fever (more probable) Hospital of 1ª de Maio

Malaise	Anorexia	Malaise	Constipation
Headache		Headache	Asthenia
Nausea		Constipation	headache
Asthenia		Asthenia	Chills
Chills		Colica Abdominal	Nausea
Anorexia			Malaise
			Anorexia

Table 3. Expert´s opinions of typhoid fever (little probable) Health center of Lombo Lombo

Malaise	Malaise	Constipation
Chills	Chills	Chills
Diarrhea	Diarrhea	Diarrhea
Constipation	Anorexia	Malaise

Table 4. Expert´s opinions of typhoid fever (not probable) Health Center of Santa Catarina

Vomiting
headache
Nausea

Table 5. Decision table

	1	1	2	2				3	3	4	4		
Conditions/Rules	**R1**	**R2**	**R3**	**R4**	R5	R6	R7	**R8**	**R9**	**R10**	**R11**	R12	Else
Constipation	**S**	**S**	**N**	**S**	S			**S**	**S**	**S**	**N**	S	
Asthenia	**S**	**N**	**S**	**S**	S	S	N	**S**	**S**				
headache	**S**	**N**		**S**	S	S	N	**S**	**S**				
Acute fever	**S**	**S**	**S**	**S**	S								
Chills	**S**	**N**			S	S	N	**N**	**S**	**S**	**S**	S	
Vomiting	**S**	**S**											
Artrhalgia	**S**	**N**											
Nausea	**S**	**N**				S	N		**S**				
Diarrhea	**S**	**S**	**N**	**S**	S					**S**	**S**	S	
Colica_Abdominal	**N**	**S**	**S**	**S**	S			**S**	**N**				
Malaise						S	N	**S**	**S**	**S**	**S**	S	
Anorexia						S	S	**N**	**S**	**N**	**S**		
Actions													
More probable	**X**	**X**	**X**	**X**	X								
Probable						X	X	**X**	**X**				
Little probable										**X**	**X**	X	
Not probable													X

Combine identical actions in Table 5.
(R1 and R2);(R3 and R4);(R8 and R9);(R10 and R11)

Table 6. Decision table

Conditions/Rules	**R1**	**R2**	R3	**R4**	**R5**	**R6**	**R7**	Else
Constipation	**S**	_	S		**S**	_	**S**	
Asthenia	_	**S**	S	_	**S**			
headache	_	_	S	_	**S**			
Acute fever	**S**	**S**	S					
Chills	_		S	_	_	**S**	**S**	
Vomiting	**S**							
Artrhalgia	_							
Nausea	_			_	_			
Diarrhea	**S**	_	S			**S**	**S**	
Colica_Abdominal	_	**S**	S		_			
Malaise				_	**S**	**S**	**S**	
Anorexia				**S**	_	_		
Actions								
More Likely	**X**	**X**	X					
Likely				**X**	**X**			
Little Likely						**X**	**X**	
Not Likely								X

Remove the redundant
(R1 and R2);(R3 and R4);(R4 and R5);(R6 and R7)

Table 7.1 Final version

Conditions/Rules	**R1**	**R2**	**R3**	**R4**	**Else**
Constipation	**S**	**S**		_	
Asthenia	_	**S**	_		
headache	_	**S**	_		
Acute fever	**S**	**S**			
Chills	_	**S**	_	S	
Vomiting	**S**				
Artrhalgia	_				
Nausea	_		_		
Diarrhea	**S**	**S**		S	
Colica_Abdominal	_	**S**			
Malaise			_	S	
Anorexia			S	_	
Actions					
More Likely	**X**	**X**			
Likely			X		
Little Likely				X	
Not Likely					X

Remove the redundant (R1 and R2)

Table 7.2 Final version

Conditions/Rules	**R1**	**R2**	**R3**	**Else**
Constipation	S		_	
Asthenia	S	_		
headache	S	_		
Acute fever	S			
Chills	S	_	S	
Vomiting				
Artrhalgia				
Nausea		_		
Diarrhea	S		S	
Colica_Abdominal	S			
Malaise		_	S	
Anorexia		S	_	
Actions				
More Likely	X			
Likely		X		
Little Likely			X	
Not Likely				X

Table 8. Classification of result (more probable)

More probable
Constipation
Acute fever
Diarrhea
Asthenia
Headache
Colica_Abdominal
Chills

Table 9. Classification of result (probable)

Probable
Anorexia
Asthenia/No
Headache/No
Chills/No
Nausea/No
Malaise/No

Table 10. Classification of result (little probable)

Little probable
Constipatio/No
Chills
Malaise
Diarrhea
Anorexia/No

The decision-making depends on the selection of the symptoms and signs observed by the physician, there is sometimes identical, redundant and contradiction actions between the doctors. To avoid these elements, we used the decision table which makes it possible to avoid the three elements as described below:

- Simplify the table.
-Determine if there are rules (columns) that represent impossible situations. If so, remove those columns. There are no impossible situations in this example.
-Determine if there are rules (columns) that have the same actions. If so, determine if these are rules that are identical except for one condition and for that one condition, all possible values of this condition are present in the rules in these columns.

3. Symptoms and Pathology

Phase 5: Implementation

The system is developed using Expert Sinta, the global classification was done using the Se logic toolbox then if not. The system includes the following module.

4. PROPOSED EXPERT SYSTEM MODEL

In general, patients go to hospitals to complain about their illnesses and medical expert system user questions patients about their illnesses and looks for symptoms in a knowledge base.

If the symptoms match what is in the knowledge base, the user gives the prescription to the patient. The diagram proposed for the medical expert system is shown in Fig. 1. This figure shows the different modules that work together to obtain a complete expert system based on rules.

4.1 System Modeling

A formal model of the proposed system is constructed using the Unified Modeling Language (UML). UML is a modeling system that provides a set of conventions for describing software engineering in terms of objects [12]. It provides diagrams providing different perspective views of system components. For our case, a use case diagram graphically illustrates the interactions between the system, the external system and the user. Use case diagrams play a

Table 11. Rule-base for the proposed system

1	If Constipation and Asthenia and headache and Acute fever and Chills and Diarrhea and Colica_Abdominal	Then More probable Typhoid Fever
2	If Anorexia and Asthenia or Headache or Chills or Nausea or Malaise	Then Probable Typhoid Fever
3	If Chills and Malaise and Diarrhea or Anorexia or Constipation	Then Little probable Typhoid Fever

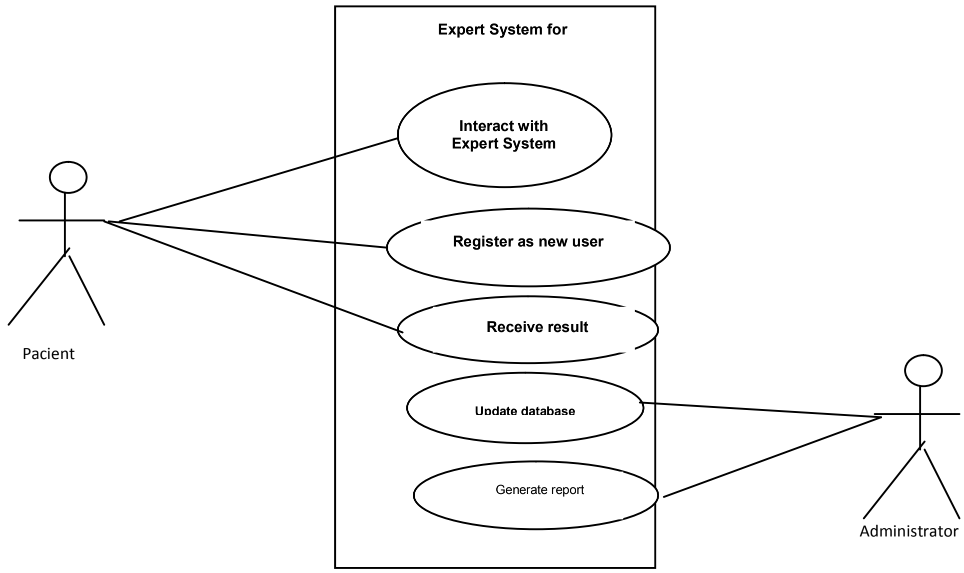

Fig. 2. Use Case diagram of XperTyph [12]

Table 12. Description of use case

Use case name	Description	Actor(s) involved
Register into Expert System	This describes the first event that must occur for a user to have full access to the Medical Expert System	Patient
Interacts with the Expert System	This describes the event where the user interacts with the system, that is, gives response to the questions asked by the Expert System.	Patient
Receives treatment	This use case describes the scenario where the user is being diagnosed and given treatment.	Patient
Update database	This describes the scenario where the Administrator updates the database in terms of the symptoms and prescription tables.	Administrator
Generate Report	Reports of daily use of System are generated	Administrator

major role in the design of the system because they serve as a roadmap for building the system structure. it also defines who will use the system and how the user expects to interact with the system. The use case diagram of our expert system is shown in Fig. 2.

The Table 12 describes the interface between the patient and the expert system administrator.

5. SYSTEM TESTING INTERFACE

The system testing interface is the structure whose role is to translate all external information to the expert system in interaction, either by feeding them information from different sources or by generating information from the system. The user asks questions and answers. In the case of XperTyph, when triggered, the system starts the session by asking the user to log in. By identifying the user, the system will already understand which domain it belongs to and what level of information it is allowed to access. This will start processing the rule base for this user. This will display a menu of options for groups of information that this user can access.

Choosing the information group that interests you at this time triggers an interaction between the user, the semantic analyzer, the inference engine, and the knowledge bases.

From there, the user can immediately obtain a particular or general summary of information, updated up to that point, or initiate a process of retrieving information or documents through search, assembled by the combination of free words or a group.

Table 13. Summary of results

Cases tested	Cases successful	Cases partially successful	Cases unsuccessful	Aproximated percentage of success
			XperTyph	
			Test cases	
Typhoid fever	50	42	5	84

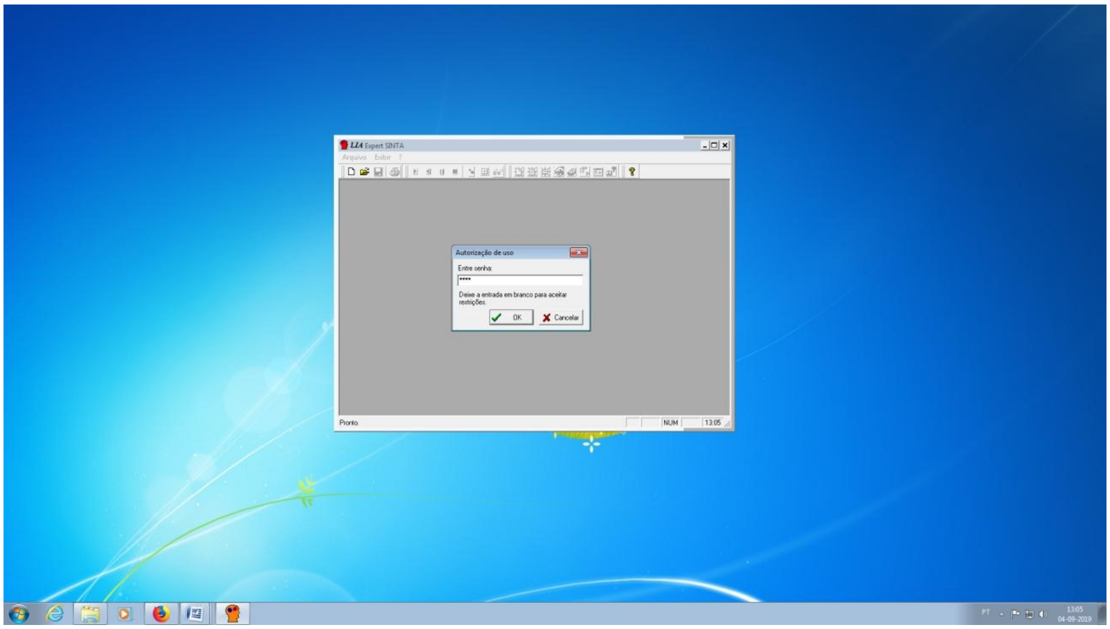

Fig. 3. Log in

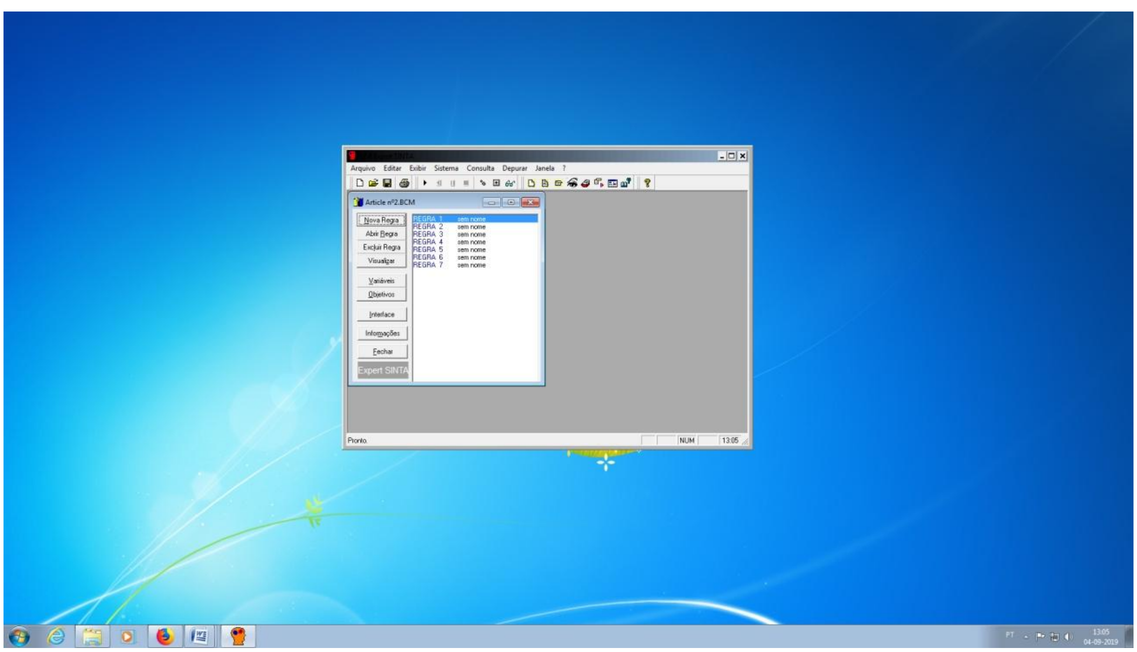

Fig. 4. Create the variables are facts and rules

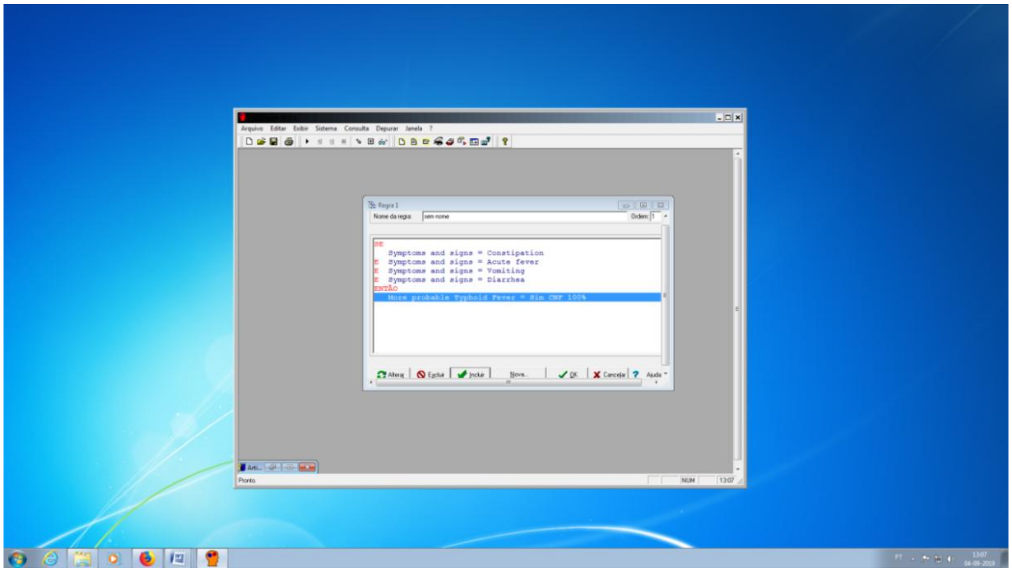

Fig. 5. Create system rules; determine premises and conclusions

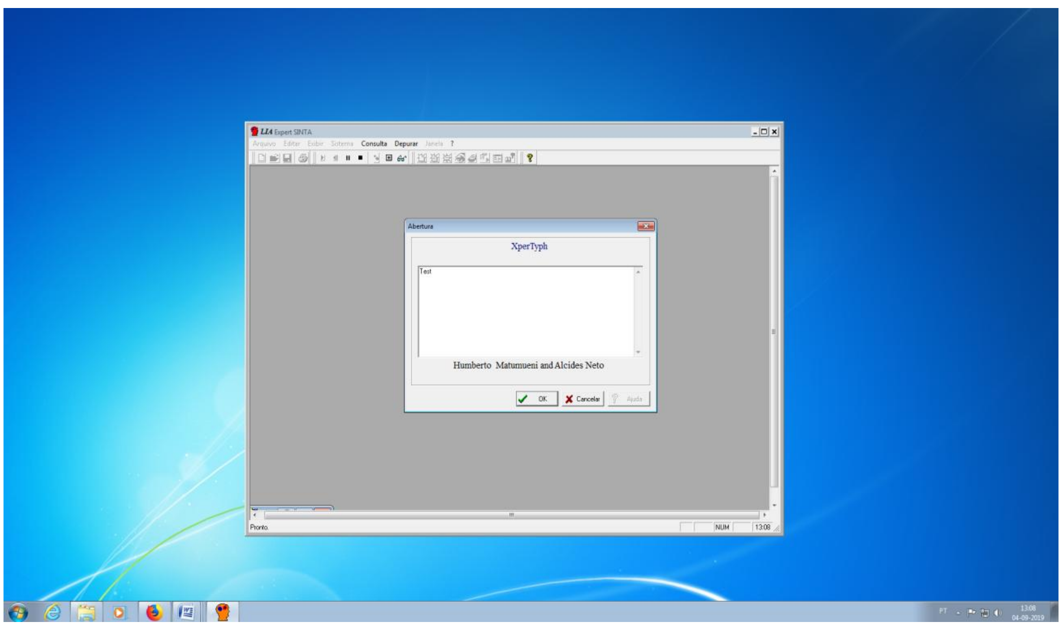

Fig. 6. Testing

6. RESULTS AND DISCUSSION

A summary of results for the above test cases and case studies is shown below:

6.1 Summary of Results

As noted above, the proposed expert system is operating satisfactorily with a success rate of about 69% in real cases. Confidence values provided were also found to be in reasonable relative order. The proposed expert system has made it possible to select patients and establish a diagnosis, but it does not work well in particular cases outside of its area of knowledge, as indicated in one of the case studies above. It will be possible to improve the success rate in real cases as new knowledge is discovered and integrated into the system. It will be possible to improve the success rate in real cases as new knowledge is discovered and integrated into the system. It will be possible to improve the success rate in as new knowledge is discovered and incorporated into the knowledge base.

An expert system based on case-by-case typhoid fever, using Expert Sinta software, records symptoms and signs with a simple knowledge base, including registration or consultation in the knowledge base. Cohen's kappa calculation was performed to verify reliability between observers and concordance between diagnoses and the expert. Cohen's kappa was introduced as a measure of agreement to avoid the problems described above by adjusting the proportional agreement observed to take into account the amount of agreement expected by chance. Cohen's Kappa is an index of the reliability of interpreters commonly used to measure the degree of agreement between the two sets of dichotomous scores or scores. The proportion of subjects for whom there is an agreement tells us nothing at all [13]. To examine how far there is an agreement other than that expected by chance, we need a different method of analysis: Cohen's kappa.Po = proportion of units where there is agreement,(Observed Agreement) Pe = proportion of units which would be expected to agree, by chance (Expected Agreement). Cohen's kappa (k) is then defined by :

$$\text{Kappa} = \frac{\text{Observed Agreement} - \text{Expected Agreement}}{1 - \text{Expected Agreement}}$$

By the time have been evaluated 65 real clinical cases whose final diagnoses are diseases included in the system. The cases were obtained from the medical file Provincial Hospital of Cabinda. The summary of results is presented in Table 12.

The kappa values in the four conditions is median typhoid Fever (k = 0.39 and 0.28).

The model validity criterion presented best content for a certain diagnosis median levels for diagnosis (k = 0.21- 0.40) for typhoid Fever.

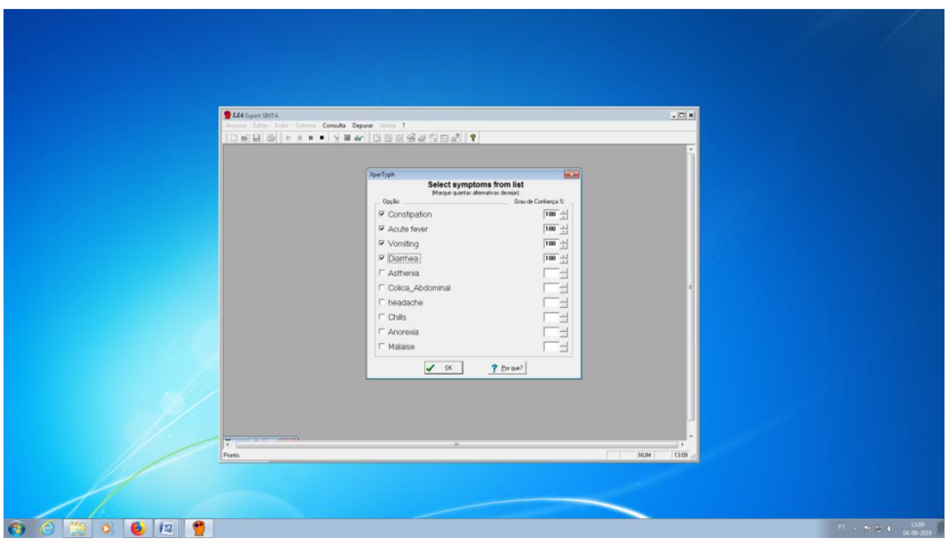

Fig. 7. Select the symptoms for the system to make the decision

Table 14. Results of evaluation (Typhoid fever)

	Diagnosis of Physician			
	Diagnosis Result	**Yes**	**No**	**Total**
Diagnosis of System	Yes	20	5	25
	No	15	25	40
	Total	35	30	65
	Pobserved	0,69		
	Pchance expected	0,49		
	Kappa Cohen	0,39		
	Fair 80 %	0,21-0,40		

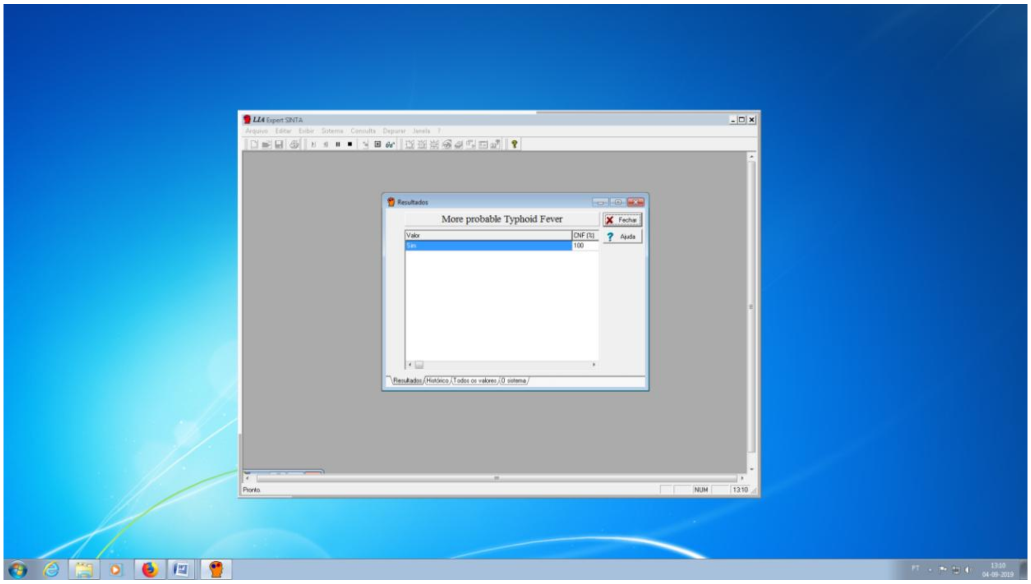

Fig. 8. System results

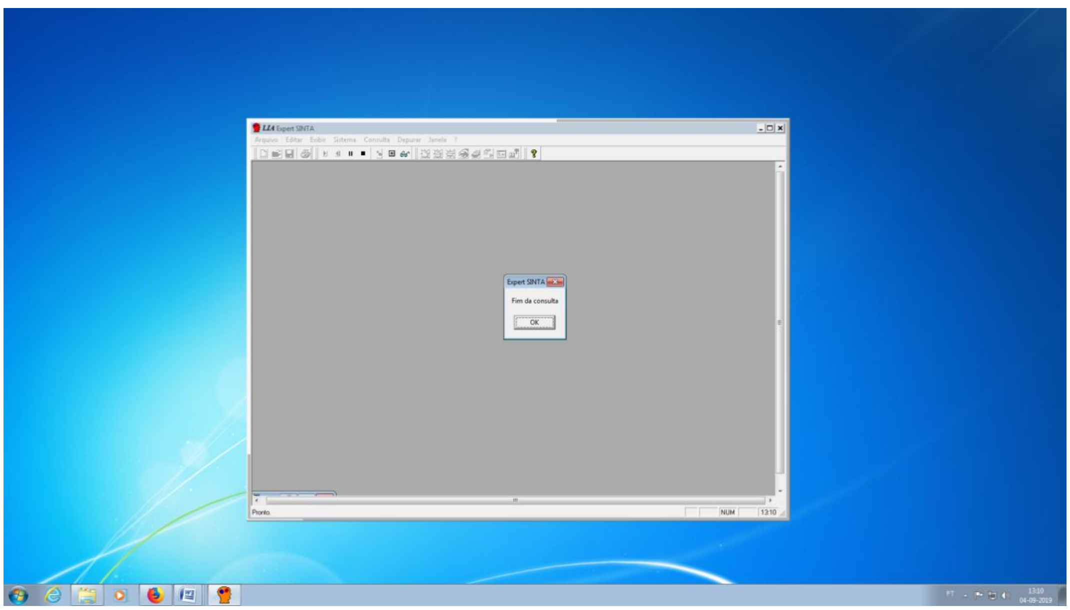

Fig. 9. The end

7. CONCLUSIONS

The expert system of medical diagnosis has been designed to help doctors for the various complications of typhoid fever and not to replace doctors. XperTyph has proven very useful in today's world of technology. When the expert's knowledge is extracted and stored, it can be used to replace the expert in case of death. The medical diagnosis will have more advantages than the expert system, knowing that only a few specialties exist in the medical field. The knowledge of this specialist can be reproduced and used in moments of extreme necessity. In this article, a system of rule-based medical experts is developed and tested to meet the various challenges of the traditional method of diagnosing typhoid fever. The researchers hope that the system proposed by XperTyph will be useful and that it can help reduce the shortcomings of doctors and make an accurate diagnosis of typhoid fever. A qualified expert would evaluate the quality of the diagnostic performed by the system, followed by a fit of the utilities. The structure of knowledge was represented by a case formalism. The typhoid fever evaluates the performance of the system practically testing it for 65 new cases for typhoid fever, where the system managed to estimate the correct diagnosis.

AVAILABLE SOURCES

Available:http://en.wikipedia.org/wiki/Decision_table
Available:http://www.cems.uwe.ac.uk/jharney/table.html
Available:http://www.cs.nott.ac.uk/~nza/G53KRR07/answer-decision-tables.pdf
Available:https://classes.soe.ucsc.edu/cmps115/Spring05/supplements/DecisionTables.htm

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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