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Addressing the shortage of Medical Doctors in Zambia: Medical Diagnosis Expert System as a solution

Macmillan Simfukwe[1], Douglas Kunda[2] and Maposa Zulu[3]

[1] Center for ICT Education, Mulungushi University,
Kabwe, Central Province, Zambia

[2] Center for ICT Education, Mulungushi University,
Kabwe, Central Province, Zambia

[3] Center for ICT Education, Mulungushi University,
Kabwe, Central Province, Zambia

Abstract

This paper presents how expert systems can help in minimizing the consequences of the shortage of medical personnel in Zambia. It also examines why it is important to develop medical diagnosis expert systems, which are to be developed for the diagnosis of diseases that are specific to Africa, as opposed to using systems that are meant for use in the Western World.
The paper further discuses the process of designing, developing and testing a medical expert system, capable of diagnosing tropical diseases, which are very prevalent in Africa.
The develop system should consist of three parts: A user interface that allows a user to interact with the system, a knowledge base which is basically a collection of facts and rules and an inference engine, which exams the knowledge base for information that matches the user's query. The knowledge base is created from information provided by a number of experienced medical doctors. The system was developed in PROLOG language.

1. Introduction

Naicker (2009) states that the health systems of sub-Saharan Africa have been adversely affected by the migration of their health professionals, and the Zambian health care system is no exception. Today, Zambia faces a severe shortage of medical personnel, especially medical doctors due to migration and limited number of medical schools. Although this is a challenge for the whole country, the rural areas are the most affected. Many rural health centers run with one or no qualified medical staff.

The following are some of the other causes of the inadequate number of trained health personnel in Zambia:

- Early retirement by health workers
- Limited places in training institutions for health personnel
- Migration of health workers to other countries for greener pastures. Some of the reasons for this include low wages, poor working environment and lack of support equipment in order to work effectively and efficiently
- -Direct impact of the HIV-AIDS. Some specialist health workers get infected with HIV-AIDS
- Some health workers decide to change careers. Some tend to join politics and other domains, which seem to have more financial prospects

The performance of a health care system is dependent on the size, distribution and skill set of its workforce, among other factors. Zambia faces a health care personnel crisis, both in terms of the employee numbers and skill mix. This shortage of qualified medical personnel is a significant obstacle to the provision of quality health care services, achievement of the national health objectives and the millennium development goals (MDG) (Annual Health Statistical Bulletin 2011, 2013).

Although medical staff include Medical Doctors, Clinical Officers, Nurses, and Mid-wives, pharmacists, laboratory technicians and environment health officers, this paper intends to focus on medical doctors. Table 1 presents data on the distribution of medical doctors in the various provinces, against the Ministry of Health's recommended staffing levels. Table 2 presents the distribution of medical doctors in various provinces, against the population in each province. The data given in the tables below pertains to medical doctors working for government hospitals. However, the staffing level pattern is the same for other medical professions, as well.

Table 1: Medical doctor staffing vs. recommended establishment

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Province	Staffing Levels	Recommended Establishment	Shortfall, %
Central	49	135	63
Copperbelt	150	305	51
Eastern	47	50	6
Luapula	46	58	21
Lusaka	214	412	48
Muchinga	-	-	-
Northern	49	117	58
North-Western	35	60	42
Southern	102	230	56
Western	41	115	64
Total	795	1,471	

Source: Annual Health Statistical Bulletin 2011, 2013*

Table 2: Medical doctor staffing vs. recommended establishment

Province	Staffing Levels	Population	Doctor-to-Patient Ratio
Central	49	1,307,111	26676
Copperbelt	150	1,972,317	13149
Eastern	47	1,592,661	33886
Luapula	46	991,927	21564
Lusaka	214	2,191,225	10239
Muchinga	-	711,657	-
Northern	49	1,105,824	22568
North-Western	35	727,044	20773
Southern	102	1,589,926	15588
Western	41	902,974	22024
Total	795	13,092,666	16 468

Source: Annual Health Statistical Bulletin 2011, 2013*

It should be noted that the World Health Organization (WHO) recommends a doctor to patient ratio of 1:1000, as stated by Mwenda (2012).

2. Problem Statement

According to the information presented in tables 1 and 2, there is a substantial shortage of medical doctors across Zambia in government-run health institutions. However, the people in rural areas more affected by this situation than their counterparts in urban areas. This because urban areas do have private clinics and hospitals, which are usually well staffed with medical personnel, medical doctors inclusive. Even though these private health institutions tend to be expensive, most urban dwellers are economically affluent and therefore able to afford to pay and receive medical care in private clinics and hospitals. Unfortunately, the same cannot be said of the people in rural areas. The following are some of the challenges experienced by the rural population as a result of medical doctor shortages in Zambia:

- Low quantity of medical care for patients due to the unavailability of doctors
- Low quality of medical care to patients due to short doctor visits
- Overworked and tired medical doctors due to the high doctor-patient ratio
- Some patients die whilst in queues waiting to be seen by the doctor
- Wrong diagnosis and treatment due to some doctors being forced to address problems for which they are not qualified
- High charges in private clinics and hospitals due to less competition

One of the solutions to the aforementioned problems lies in increasing the number of medical doctors. However, it takes at least seven years to produce a medical doctor and the capacity of the training institutions is also limited. This means that Zambia would be unable to see a drastic increase in the number of medical doctors, available to provide health care in government institutions. On the other hand, the country's population is increasing, a fact that would keep on affecting the doctor-patient ratio.

Another solution is the adoption and use of medical expert systems. In artificial intelligence, an expert system is a computer system that emulates the decision making ability of a human expert (Mandal et al, 2013).

Merritt (2000) defines an expert system as a computer application which embodies some non-algorithmic algorithmic expertise for solving certain types of problems. Figure 1 shows the structure of an expert system.

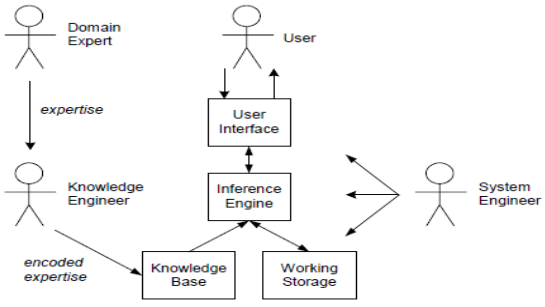

Fig.1. Expert system components and human interfaces

Source: Merritt, 2000*

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3. Medical Diagnosis Expert Systems

There are a number of medical expert systems that have enjoyed tremendous success in the Western world. A medical diagnosis expert system is an expert system that helps in the diagnosis of diseases and gives recommendations on the treatment methods to be carried out (Patra et al, 2010).

Three medical diagnosis systems namely Mycin, Davial and Oncocin were accessed for use in Zambia.

3.1. MYCIN

MYCIN is a medical diagnosis expert system that was developed to capture the expertise of a human expert on blood diseases. Physicians used it to diagnose and treat patients with infectious blood diseases caused by bacteria in the blood and meningitis (Shortliffe, 1976).

Strengths

1. It provides accurate and quick diagnosis
2. Its knowledge base was develop with the help of the best human practitioners, as a result it is extremely detailed and is very competent
3. It is comprehensive and considers every disease, present in it knowledge base
4. It does not forget or overlook any details, no matter how obvious the disease is

Weakness

1. It is only available to diagnose infectious blood diseases
2. It does not follow up on previous decisions
3. Bases advice on the data available at that particular time
4. The User interface is only in English

3.2. DAVIAL

DIAVAL is a medical expert system that was developed to diagnose heart diseases through echocardiography and other cardiac anomalies (Diez et al, 1997).

Strengths

1. Its capability to explain its reasoning, in order to justify its results and recommendations it offers
2. Easy to use

Weaknesses

1. It is only available to diagnose heart diseases and other cardiac anomalies
2. It tends to over diagnose in three ways: by overestimating the severity of an anomaly, such as diagnosing moderate or severe mitral stenosis instead of mild stenosis; by offering too specific results, such as diagnosing acute regurgitation when there was not enough evidence to determine whether it was acute or chronic; and, in general, by overestimating the probability of anomalies, which occasionally lead to including some diagnoses that should have remained under the certainty threshold
3. The user interface is in only English

3.3 ONCOCIN

ONCOCIN is a medical expert system that was developed to capture the expertise of a human expert on cancer. It was designed to assist physicians in the treatment of cancer patients receiving chemotherapy (Shortliffe et al, n.d.).

Strengths

1. Fast and easy to use
2. It allows an interaction with previous information or historical data of the patient's previous visits to the clinic
3. It uses initial data about the patient's diagnosis, data about previous treatment, results of current laboratory tests, plus the protocol-specific information in its knowledge base to generate recommendations for appropriate therapy and tests
4. It provides explanation for each recommendation
5. It provides hard-copy backup to complement the on-line interaction and facilitate communication among clinic personnel.
6. It has a large knowledge base

Weaknesses

1. It is only able to diagnose cancer
2. The user interface only supports English language

4. Zambian Medical Diagnosis Expert System (ZAMDES)

The three systems analyzed above have been successfully used in Europe and the Unites States of America. However, they are not appropriate for use in Africa and in particular Zambia, since they are unable to

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diagnose tropical diseases, such as malaria, cholera, dysentery and other diseases, which terrorize the majority of Africans, especially those in rural areas. This article intends to report about the design, development and testing of the Zambian medical expert system (ZAMDES) that is capable of diagnosing tropical diseases. The following are the requirements of ZAMDES:

4.1. Analysis and Design

User Requirements

- The language to be used is English.
- The system shall contain 50 diseases in its knowledge base.
- The system shall provide a console interface through which a user can interact with the system.
- The system shall prompt the user to enter feature/features which indicate a condition of a disease, in particular one apparent to the patient. These feature/features are also known as symptoms.
- The system shall identify the nature of an illness (disease) based on symptoms.
- The system shall recommend the use of particular medication or treatment based on the nature of an illness.

Functional Requirements

Data Input: Data such as the symptom which indicates a condition/disease will be input directly through the keyboard by the user.
Processing: Data processing will be carried out after the symptoms of a disease have all been entered into the system.
Data Output: Output of the information will be displayed on the monitor. This information will include the identification of the disease/condition and the recommendation of the medication for treatment.
User Interface: The system will communicate with the user through the console.
Operating system environment: The system will run on Microsoft windows 7

Non-functional Requirements

Speed: The system must not take very long as far as processing inputs is concerned.
Usability: The system must be easy to use, understand and learn
Reliability: The system must maintain its performance over time.
Robustness: The system must be able to handle error conditions
Figure 2 shows the design of ZAMDES:

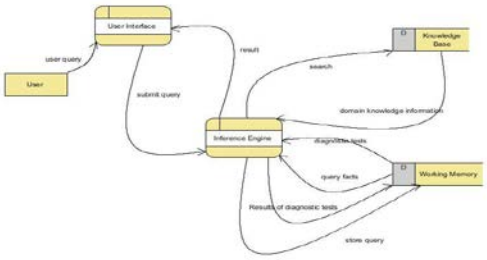

Fig.2. DFD of ZAMDES

4.2. Development

ZAMDES was developed using the SWI-Prolog platform and the language of development was prolog. Figure 3 below shows part of the code and knowledge base for ZAMDES:

```
domains
 symptom = symbol
 treatment = symbol
 Stringlist= string*
predicates
 start
 reading(stringlist)
 results(stringlist,stringlist,stringlist)
 diagnose(string)
 cause(string,[symptom],[treatment])
clauses.
```

Fig.3. ZAMDES source code and knowledge base

4.3. Testing

A number of tests were carried out regarding malaria, dysentery and cholera diagnosis. Symptoms or conditions were input in the system and it gave correct diagnosis and treatment recommendations. Figures 4 and

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5 below shows some results for the tests that were carried out.

```
**********ZAMBIAN MEDICAL DIAGNOSIS EXPERT SYSTEM**********

**************************WELCOME**************************


************** MENU **************
 1. Diagnose Patient
 2. Exit

Enter your choice:
|:
```

Fig.4. Medical expert system menu

```
*****Enter a Minimum of 3 Symptoms*****
Enter a Symptom (followed by a period)
|: nausea.

Do You Wish To Enter Another Symptom? Type(yes/no) followed by a period.
|: yes.

Enter Another Symptom (followed by a period)
|: dehydration.

Do You Wish To Enter Another Symptom? Type(yes/no) followed by a period.
|: yes.

Enter Another Symptom (followed by a period)
|: wateryStool.

Do You Wish To Enter Another Symptom? Type(yes/no) followed by a period.
|: no.


Confirmed Symptoms are:
[nausea, dehydration, wateryStool]

The Diagnosed Disease(s) is:
cholera

Recommended Treatment is:
[ciprofloxacinHydrochloride, vibramycin]
true
```

Fig.5. Interactive session with diagnosis and medication recommendation

5. Lessons Learnt

Although ZAMDES has not been deployed in the Zambia rural health centers, a number of lessons were learnt during development and testing. The major lessons learnt from this research are:

Lesson 1: it is important to gather knowledge about diseases and conditions from several different experts for the knowledge base to be reliable.

Lesson 2: Thorough testing of medical diagnosis expert system is very important because wrong diagnosis may lead to wrong treatment using drugs that may have side effects and even worsen the patient's condition.

Lesson 3: Medical diagnosis expert systems have a lot of potential and can help address the shortage of medical doctors, especially in rural areas.

Lesson 4: Sensitization of users is vital for the success of medical diagnosis expert systems. Patients are used to seeing medical doctors in person to have confidence in the diagnosis and treatment. There might be psychological barriers to entrusting ones life to a machine.

6. Conclusion and future work

A medical expert system, customized to diagnose tropical diseases, would go a long way in terms of alleviating the challenges, faced by the poor people in rural areas, resulting from having medical personnel shortages.

The patients can get a quick diagnosis, together with a recommendation of the medication, which can be acquired from a chemist or drug store.

This would in turn save a lot of lives, whose input is very much needed to uplift the Zambian economy.

In future, we would like to a user interface that supports the seven Zambian local languages, apart from English. This would help serve those users that are unable to read and write in English language.

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Macmillan Simfukwe
Master of Applied Informatics – 2011
Bachelor of Applied Informatics – 2009
Mulungushi University, Lecturer (2011 – Current)
Northrise University, Lecturer (2011)
Research interests: expert and decision support systems in health care delivery, use of ICTs in business, Enterprise Systems
Professional Associations: Member of the ICT Society of Zambia and the Zambia Health Informatics Association

Douglas Kunda
PhD in Computer Science, University of York
Bachelor of Engineering (Electronics and Telecommunication), University of Zambia
Current Employment: Mulungushi University, Director/Dean of the Center for ICT Education
Previous Employment: IFMIS Project Manager, Ministry of Finance and National Planning Of the Republic of Zambia (2002 - 2008)
Research Interests: Component based software engineering, data structure and algorithms, agile software development, social-technical systems, Enterprise Resource Planning Systems (ERPs), information systems
Professional Associations: Member of ACM and Fellow of the ICT Society of Zambia

Maposa Zulu holds a Bachelor of Computer Science Degree and is a member of the ICT Society of Zambia