NILE UNIVERSITY OF NIGERIA ★ SCHOOL OF POSTGRADUATE STUDIES

RELEVANCE OF USER DATA COMPLETENESS IN RESOLVING DIFFERENTIAL DIAGNOSIS IN MEDICAL EXPERT SYSTEM OPTIMIZATION

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, NILE UNIVERSITY OF NIGERIA, ABUJA IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN COMPUTER SCIENCE.

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DECLARATION

I, ***Ismaila Lukman Enegi, with ID-151123005***, hereby declare that this thesis titled "**Relevance of User Data Completeness In Resolving Differential Diagnosis in Medical Expert System Optimization**" has been carried out by me under the supervision of **Prof. Nwojo Agwu Nnanna**. It has not been presented for award of any degree in any institution. All sources of information are specifically acknowledged by means of reference.

....

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CERTIFICATION

TITLE OF THESIS
Relevance of User Data Completeness In Resolving Differential Diagnosis in Medical Expert System Optimization

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DEDICATION

I dedicate this entire research work to **Allah** (Azzawajal) for granting me the opportunity, wisdom and strength to take this work to completion, & to my lovely parents for their prayers, support and encouragements *Alhamdulillah*.

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ABSTRACT

This research effort implemented a technique for resolving differential diagnosis in medical disease expert systems. This was achieved by collecting additional information from users during diagnosis which help to correctly decide which new rule will be asserted to the working memory before feedback can be deduced after proving that a user is suffering from a particular disease by confirming all the symptoms. Our approach correctly resolves differential diagnosis by ruling out similar diseases which match user disease symptoms and enhances the general accuracy of the expert system due to sufficient user information made usable to the system. This work presents a general solution to most significant problem of differential diagnosis which is neither restricted to a particular disease nor medical domain as compared to the work of other researchers where techniques to resolve differential diagnosis were restricted to a particular disease type. The system can be further optimized by providing the probability value when a goal is achieved as well as medical prescription after diagnosis is completed.

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Definition of terms

Agenda: When rules are satisfied by the program, they are added to a queue called the agenda. Agenda refer to an unordered list of all the production rules whose antecedents are currently satisfied.

Antecedent: The antecedent refer the condition that must be satisfied. If the antecedent is satisfied, then rule is triggered and this is termed ”fire”. The consequent is the action that is performed when the rule fires.

Differential Diagnosis: differential diagnosis is the act of distinguishing of a particular disease or condition from others that present similar clinical features.

Expert System: a computer system that emulates the decision-making ability of a human expert

Factual Knowledge: It is the information widely accepted by the Knowledge Engineers and scholars in the task domain.

Fuzzification: This means the first step in the fuzzy inferential process. It involves a domain transformation where crisp inputs are transformed into fuzzy inputs. Crisp inputs are exact inputs measured by sensors and passed into the control system for processing. When rules are satisfied by the program, they are added to a queue called the agenda[2].

Heuristic Knowledge: It is about practice, accurate judgment, one's ability of evaluation, and guessing.

Knowledge Acquisition: is the process used to define the rules and ontologies required for a knowledge-based system. The effectiveness of any expert system greatly depends on the quality, completeness, and accuracy of the information stored in the knowledge base. The knowledge base is formed by readings from various experts, scholars, and the Knowledge Engineers. The knowledge engineer is a person with the qualities of empathy, quick learning, and case analyzing skills[24].

Model-based reasoning: refers to an inference method used in expert systems based on a model of the physical world

Knowledge representation: It is the method used to organize and formalize the knowledge in the knowledge base. It is in the form of IF-THEN-ELSE rules.

Acronyms

AI Artificial Intelligence.

KB Knowledge Base

ES Expert System

DD Differential Diagnosis

eMycin Essential Mycin

GUI Graphic User Interface

JPL Java Prolog Interface

Keywords
Expert System, Knowledge Acquisition, Model-based reasoning, Differential Diagnosis, Fuzzification, Deductive system, facts, rules

CHAPTER ONE

Introduction

1.1 Background to the Study

A Medical Expert system (ES) can be defined as: A program that attempts to mimic human expertise in the field of medicine and diagnosis by applying inference methods to a specific body of knowledge. It has become obvious that the bulk of the underlying technology we have today is derived from incremental research on bio-medical expert systems.There are several expert systems used in the medical field. *Mycin* is one of the earliest rule-based expert systems *written in Lisp as the doctoral dissertation of Edward Shortliffe under the direction of Bruce G. Buchanan, Stanley N. Cohen and others in 1970's* for the purpose of diagnosis of infectious diseases. Medical applications and software packages are thus far generally unavailable from the young artificial intelligence industries[1].
Medical expert systems have begun to emerge progressively as researchers in medical artificial intelligence are making success in key areas such as knowledge acquisition, model-based reasoning and system integration for clinical environments [1]. It has become very important for computer scientists and medical professionals to work with combined effort in order to understand the current state of such research as well as the theoretical and logistic barriers that remain. This can promote the potentials of researchers in making sure that medical disease diagnosis works efficiently and possibility of software error is reduced to the barest minimum before any useful system can be publicly made available.

1.2 Expert System

Properly regarded as computer software an ES is a division of computer science research called Artificial Intelligence (AI). The scientific goal of AI is to understand intelligence by building computer programs that exhibit intelligent behavior. It is responsible for the concept and method of symbolic inference, or reasoning by a computer, and how the knowledge utilized to make those inferences are represented inside the machine for a domain use.

Generally, the term intelligence covers many cognitive skills, involving the ability to solve problems, learn, and understand language; AI addresses all of those. But most progress to date in AI has been made in the area of problem solving – concepts and methods for building programs that reason about problems rather than calculate or formulate a solution.

AI programs that achieve expert-level competence in solving problems in task areas by bringing to bear a body of knowledge about specific tasks are called knowledge-based or expert systems. Often, the term expert systems is reserved for programs whose knowledge base contains the knowledge used by human experts, in contrast to knowledge gathered from textbooks or non-experts. More often than not, the two terms, expert systems (ES) and knowledge-based systems (KBS), are used synonymously. Taken together, they represent the most generalized type of AI application. The task domain is the area of human intellectual endeavor to be captured in an expert system. Task means some goal-oriented, problem-solving activity. Domain refers to the subject within which the task is being performed. Typical tasks are diagnosis, planning, scheduling, configuration and design. An example of a task domain in the medical field is medical disease diagnosis which will later be discussed in in this report in chapter 4 [2].

1.2.1 Major components of typical Expert System

Knowledge Base This refers to a collection domain-specific and high-quality information (knowledge). Knowledge is required to exhibit intelligence. The success of any ES majorly depends upon the collection of highly accurate and precise knowledge. An Expert System shell provides one or more knowledge representation schemes (in the form of knowledge bases) for expressing knowledge about the application domain.

Inference engine This represents the main processing element of the expert system. The inference engine selects rules from the agenda to fire. If there are no rules on the agenda, the inference engine must obtain information from the user in order to add more rules to the agenda. It makes use of information from the knowledge base, in order to draw conclusion for a situation. It is responsible for gathering the information from the user, by asking various questions and applying it wherever necessary. It uses information and relationships from the knowledge base and to provide answers, predictions and suggestions the way a human expert would.
Complete inference engine can be divided into following functional elements:

Control system- determines the order of testing the knowledge base rules.
Rules interpreter - defines a boolean (true, not true uncertainty factor) applications rules.
Explanation mechanism justifies user the process of reasoning and generates report.

Working Memory Working memory contains the data that is collected from the user during the expert system session. Values in working memory are used to evaluate antecedents in the knowledge base. Consequences from rules in the knowledge base may create new values in working memory, update old values, or remove existing values.

User Interface This represents the medium of communication between the user and the system. The user interface is usually not a generic part of the Expert System technology, and was not given much attention in the early years of the development of Expert Systems. However, it is now widely accepted that the user interface can make a critical difference in the perceived utility of an Expert System regardless of the system's performance. In some cases, the users enters a request in Natural Language, dialog boxes, command prompts, forms, or other input methods, and the Expert System processes the request to provide a result by using an Inference rule(s) to select the appropriate solution from a Knowledge Base[24].

1.2.2 Medical Expert System for Disease diagnosis

Medical ES's are AI softwares designed and empowered with the capability of a medical expert to diagnose a patient if infected with a disease, it is only possible to diagnose diseases whose details are provided and usable to the software.

1.2.3 Platform

There can be a number of platforms for ESs. Research efforts are majorly designed and implemented as offline desktop applications or web-based application. It is convincing that the computational power is available with the recent breakthrough in hand-held device technology therefore expert systems software can now be design to work in hand-held devices.

Trust in Expert System The confidence of every user of a system is independent of the platform but greatly depends on accuracy, resourcefulness, and security of the software. To enhance user confidence whether medical patients or professional medical doctors, our model was design to ensure better accuracy in medical disease diagnosis.

1.2.4 Problems/Challenges of Expert System

Major threat posed for expert systems in the academic literature are the knowledge acquisition problem, complexity of dynamic rules which can greatly affect efficiency and accuracy. Obtaining the time of domain experts for any software application is always difficult, but for expert systems it was especially difficult because the experts were by definition highly valued and in constant demand by the organization. As a result of this problem, a great deal of research in the later years was focused on tools for knowledge acquisition, to help automate the process of designing, debugging, and maintaining rules defined by experts. Some complex expert systems need well defined accurate rules to properly handle their dynamic nature and if these requirements are not met, the efficiency may suffer.

1.3 Statement of the Research Problem

The precision and correctness of a medical expert system is very crucial to both the users and developers. Users' cooperation and confidence is required when using the system and this can only be achieved if they trust the system accuracy. Constant review of available research efforts for further exploration of some possible ways of system optimization. This research effort aimed at enhancing the quality of diagnosis by addressing the problem of differential diagnosis which is a key factor necessary for making critical decision when more than one diseases contain the same symptoms from the knowledge base.

1.4 Aim and Objectives of the Research

The aim of this research is to design a medical ES which does not only perform medical disease diagnosis but also, has the capability of using user data to resolve the problem of differential diagnosis. Objectives of this research include:

i To resolve the problem of Differential Diagnosis in medical expert systems;

ii To improve the accuracy of medical disease diagnosis;

iii To provide clear documentation of decision making factors in disease diagnosis;

iv To reduce the time taken to diagnosis diseases.

1.5 Justification

Medical expert systems are very sensitive machines and the slightest mistake or error due to malfunction can lead to loss of human life. This makes it much more important to ensure that medical ES are always accurate in there working mechanisms and results. Also, a medical expert system can be designed to be error free whereas perfect human medical expert does not exist and the available few are expensive to hire and even more difficult to get all the time [25]. Well maintained medical expert systems are less cost incurring when compared to the cost of hiring human medical doctor and additionally, efficiency and effectiveness of a human diminishes for several reasons over time as well as possibility of natural human error that can be prevented in the case of medical expert system applications.

1.6 Scope of Work

In this project, much emphasis is given to techniques to efficiently resolve differential diagnosis that occur during medical disease diagnosis. about twenty diseases were selected based on their frequency indexes (Commonness) in our local environment, contribution to death rate, and similarity among disease during diagnosis. The expert system accept inputs in text format only. Although not implemented in this research, diagnosis base on image input can be included at later stage of this work. Generally, this system accept disease symptoms as queries from users and return feedback when inputted symptoms match a disease in the knowledge-base.

1.7 Theoretical Framework

An expert system is one of the most important application areas of AI. It can be considered as a software which operates under the guide of some sophisticated rules in a computer system similar to a human expert. It explains their reasoning or suggested decisions, display intelligent behavior, draw conclusions from complex relationships [6]. The main conceptual source of expert system is knowledge. ES can expand to include a knowledge acquisition component the processes data and information into rules. Expert systems has number of application areas like decision making, prediction, planning, monitoring, process control, forecasting, diagnosis etc. In medical ES, patients are examined through questions and the ES consults it knowledge base and draw conclusion on the medical advice or prescription for the patient however, the use of patient details, environmental factor etc. enhances the accuracy of diagnosis also help to resolve the problem of DD which is also a general challenge even in the case of human expert. In this project, we explore this idea and demonstrate that DD can be solved by implementing this technique.

1.8 Summary

In this section, we provide a general introduction of what this research effort is all about. We explain the importance of an accurate and efficient medical expert system to a medical doctor as well as medical patient. Our main concern in this area is to improve system accuracy. In view of this, a system model has been proposed and detail explanation of how the research problem was design and implemented are available in chapter three and four respectively.

CHAPTER TWO

Literature Review

2.1 Introduction

Several proposed ES's exist so far in medical diagnostics. To ensure efficient diagnosis, it is necessary for ES to work with necessary resources like patients medical history, environmental factors, detail properties of the patients symptoms, as well as results of all other external test conducted. This chapter discussed some of the efforts by different researchers organized into the concepts that interest this research.

2.2 Research Background

The overall idea of this research was based on reviewed efforts of the following papers. Major concepts of Medical differential diagnosis was considered in enhancing the credibility of this work.

2.2.1 Medical Diagnosis

Research efforts to enhance medical disease diagnosis include the work of H. Kalita *et al.* [3] whose work aimed to facilitate the diagnosis of common rice diseases on the basis of the user responses made against the queries related to a particular disease symptoms. this is done when users or farmers provide the symptoms of a rice plant disease in their farm for diagnosis so as to know the proper treatment [4]. His effort however include accurate symptom description into the ES which is an important aspect of our work. The below 2.1 shows the Architecture of the proposed system which was considered useful to design model-based ES.

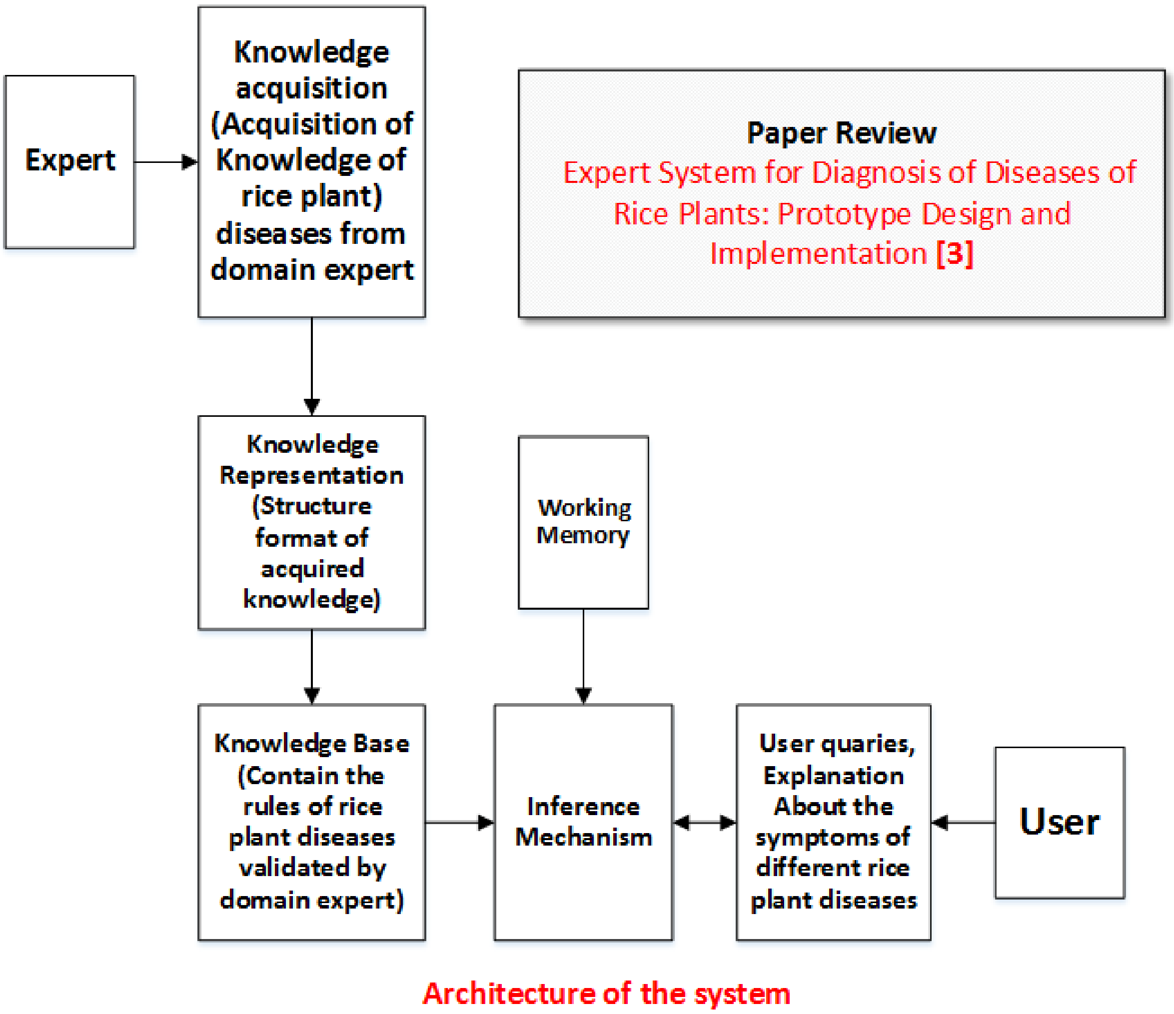


Figure 2.1: Architecture of the rice disease diagnosis system[3]

The work of M. Khachidze *et al.* [4] propose a conceptual approach to knowledge representation with variety of features without information lose and his algorithm has a binary attribute feature which describe the property of a symptom this helps to counter the problem of imprecision, incomplete and subjective data, which described the condition of the patient in medical expert system. A. Keles *et al.* [5] present expert doctor verdis by extracting fuzzy rules which utilities advanced medical information system containing various medical services supported by information technologies, with ES capabilities in a single system for vertebral column disease diagnosis. The work of R. P. Ambilwade considers a Medical expert system which uses knowledge about a disease and facts from patients to suggest diagnosis of diabetes[6]. O. Berezsky *et al*

[7] provide ES with image analysis algorithm, knowledge based reasoning and decision support system component. We considered this approach to be quiet outstanding compared to the research efforts of others, although our research aim is to work with detail information from user in order to resolve DD.

2.2.2 Rule Based Expert System

The following papers focused on rule-based concept of expert system. L. Lhotsk *et al.*[8] explore efficiency enhancement of classical rule bases diagnostic expert system which uses blackboard control structure for more knowledge bases of the same syntax in parallel. the work of M.A. Kadhim *et al.* research proposed a tool for constructing rule-based expert system called DDTRES (Diagnosis Domain Tool for Rule-based Expert System), this tool provide variety of functions to facilitate the development of expert systems for practical problems in different diagnosis domain [9]. R. Karim *et al* proposed a Rule-Based Inference Methodology using the Evidential Reasoning (RIMER) approach was adopted to develop an expert system, which is named the Belief Rule-Based Expert System (BRBES). The system can effectively handle various types of uncertainty in knowledge representation and inference procedures[10]. This is quiet different from The approach of L. Rizzo *et al* [11] which involves modeling metal workload via ES. He also concluded that quantification of the validity and the sensitivity of developed models suggest that rule-based ESs can be successfully built for mental workload modeling and assessment because their inferential capacity lies between the inferential capacity of two trusted instruments. M.Ayman AL-Ahmar presents a modeling and development of a prototype expert system that helps software project managers and software engineers in selecting the appropriate software development methodology. The developed system is successfully designed as rule based expert system supported with object oriented modeling[12].

2.2.3 Fuzzy Logic Expert System

A. Baghel *et al* [13] carried out research to explore a system which uses fuzzy logic to handle the uncertainty and ambiguous data. This system adapts the fuzzy logic reasoning technique. Q. Yang *et al*[14] proposed a model of a multi-agent diagnosis helping system (MADHS) with Fuzziness and uncertainty incorporated into decision trees to form the reasoning mechanism of agents. Model and reasoning mechanisms are implemented using Java, Java Agent Development Framework (JADE), Java Expert System Shell (JESS) and NRC FuzzyJ Toolkit. N. H. Phuong *et al.* [15] explore an approach to developing a fuzzy rule based expert system shell combining positive and negative knowledge for medical consultations called FuzzRESS. The appraoch of M. Hossein [16] involves a fuzzy rule-based expert system which applies fuzzy linguistic variables to express the level of qualitative evaluation and criteria of experts. Similar fuzzy approach is done by N. Hassan *et al*[17] who adopts the concept of fuzzy soft set theory to develop a knowledge-based system in medicine and devise a prediction system named fuzzy soft expert system consisting of four main components. These are a fuzzification which translates inputs into fuzzy values, fuzzification of data sets to obtain fuzzy soft sets, a new fuzzy soft set by normal parameter reduction of fuzzy soft set and an algorithm to produce the resultant output.

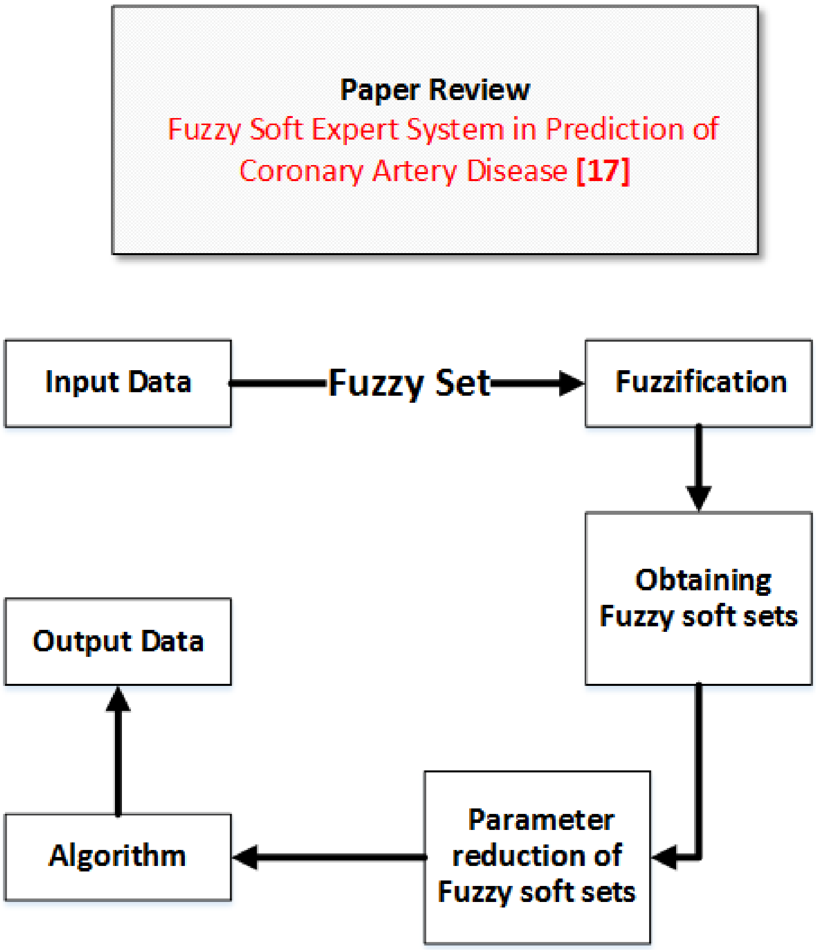


Figure 2.2: Basic structure of a fuzzy soft expert system[16]

2.2.4 Differential Diagnosis

H. A. Guvenir *et al.*[18] presents solution to differential diagnosis of erythemato-squamous diseases incorporating decisions made by three classification algorithms:

nearest neighbor classifier, naive Bayesian classifier and voting feature intervals which enables doctors differentiate between six types of erythemato-squamous diseases using clinical and histopathological parameters obtained from a patient[18]. A. Ameri *et al*[19] Introduces CDXS a differential diagnosis expert system which is based on their algorithm. The system is still under training, but is being used for educational purposes at Shahid Beheshti University of Medical Sciences. M. Mottalib *et al*[20] presents a Bayesian classification approach to identify the onset of diabetes mellitus in patients using a well-known data set as the sample.

2.2.5 Expert System Shell

L.W. Santoso *et al.* [21] proposed an expert system shell algorithm for forward chaining and backward chaining in inference engine to accommodate balance binary searched tree and binary sort that have good performance in large database.due to the two algorithms of knowledge acquisition in inference engine and supported by certainty factor calculation. L. Shapiro*et al* [22] claim that given a knowledge base file of relative weights for the input features of a group of medical conditions, a user can enter features of individual cases interactively or in either of two streamlined modes. The considered Bayesian shell permits rapid evaluation of Bayesian knowledge bases in support of knowledge base and program development. It can be embedded in other programs that utilize Bayes' theorem to evaluate any body of data, clinical or otherwise. E C. Ogu *et al.* [23] emphasize basic concept of ES Shells with highlights on basic usage and creating some form of in-depth generic expose into some of the component facilities and utilities they provide and proposing a more efficient model for Knowledge Acquisition which would make the Knowledge Acquisition Bottleneck of developing Expert Systems a thing of no more concern. T F. Thompson *et al.* [24] proposed caster which uses the Heracles qualitative modeling environment, a shell generalized from the Mycin medical diagnosis system. We agree with his claim that removing knowledge-base from a medical diagnosis system, but retaining the rule base , led to a reusable expert shell.

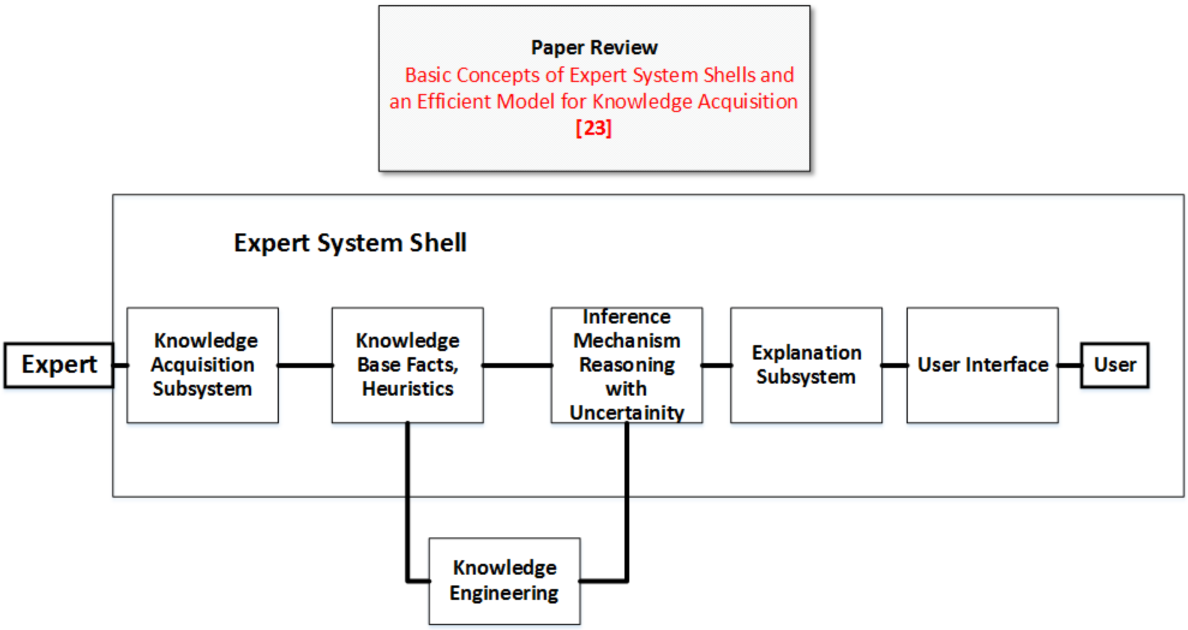


Figure 2.3: Generic Components of an Expert System Shell

2.3 Research Gap and Proposed System

Medical Expert systems are indeed very sensitive software and their accuracy must be ensured at all time. Reviewed research efforts above shows that several researchers have tried to enhance expert system accuracy and efficiency by providing algorithms and methods which helps to solve accuracy issues in specific medical disease diagnosis. The identified research gap is to address the problem of differential diagnosis through a more general method of approach. Our research model is based on collecting additional information from users which are used to assert new rules at run time for resolving the problem of DD when multiple goals are reached in medical diseases. This work helps resolve DD in wider range of situations including other domain unlike the common approach of finding a technique to resolve a particular disease.

2.4 Summary

In conclusion, the above reviewed papers generally focused on optimization, medical ES design and correct diagnosis of specific medical diseases. In the research work, we aim to evaluate the efficiency difference between rule-base ES built in conventional programming languages(function/logic) and Shell base medical expert system. More emphasis will be given to ES shells and eMycin to be specific. The above various concepts were considered in order to give us an overview understanding and relationship between the system we propose and other similar approaches in the field.

CHAPTER THREE

Research Design And Methodology

3.1 Introduction

In This chapter, we discuss the general methodology followed in carrying out this research work as well as the system analysis and framework that assisted in achieving the project design and development during the early stage in order to provide guidance in the desired direction at later stage of this project. We adopted Agile through the processes of Requirement analysis, System Analysis, System design, Implementation, Results analysis & Testing in other to cope with the dynamic nature of disease symptoms and how diagnosis can be done in cases where DD exist. Important system developmental tools have also been highlighted so as to ensure better understanding.

3.2 Feasibility Studies

In this project, we evaluated the possibility of the research work with our available resources which includes cost, Knowledge-base (KB) source, timeline, our software requirements.

Cost This project does not require any special cost incurring resource.

Knowledge-base Source During this project, we consulted two practicing medical doctors from different hospitals for medical disease diagnosis domain knowledge base and other professional guidance.

Timeline We initially assume the project period of 6 months to be enough, but because it was difficult to get expert system shell written in prolog, we took extra time to write this disease diagnosis system from scratch and implement the model differential diagnosis technique.

Software This project is implemented using prolog programming language because it's designed to ease the process of expert system through its in-built powerful inferential engine, building an expert system shell is easier. prolog also makes it possible to design an error free, user friendly interface to smooth interaction by connecting to java jpanel through its JPL module. This final output of this project was generated to an executable file

3.3 Requirement Analysis

Major Requirements of this research includes, Domain Expert for data collection which was processed and made usable to the system as knowledge base. production rule for the expert system. The software developed in this research is a prolog program that can be executed with any prolog compiler. However some relevant System requirements and dependent software include:

Minimum System Requirements

1. **Computer**
    - **OS Support** OS Support Win7 x64, WinXP, WinVista, Win7 x32, Win8 x32, Win8 x64, Win10;
    - **RAM Memory** 128MB and above
    - **Memory Disk** 512MB and above
2. **SWI-Prolog** multi-threaded version 7.4.x
3. **Java Prolog Interface API** JPL 2.0.2
4. **Java JDK** Java Development Kit - jdk 8

3.4 System Analysis and Research Approach

This project explore various concepts in previous research work in the field of medical disease diagnosis, and consider a method of achieving the project objectives by providing a simple and optimized ES's model which demonstrate the relevance of user data completeness in resolving differential diagnosis

3.5 System Design

This Research adopted a model approach in general system work flow of a medical ES and implemented a technique which help to resolve DD. This method has rarely been the focus of most researchers in the field of medical ES. Implementation of our proposed solution to resolving differential diagnosis follow conventional medical ES approach which involves collecting patient information and matching it with underlying rules for correct deduction and precise response to user. since this software can also be used as support for efficient diagnosis by medical professionals, it considers facts and symptoms to provide diagnosis. Medical ES uses knowledge about the diseases and facts about the patients to suggest diagnosis. Medical ES consists of five major components:

1. Knowledge base which contains the specific knowledge related to the area of application of the system.
2. Database acts as a working memory and contains current facts or past data.
3. Rule-Base to supports the work with the knowledge in order to obtain correct result.
4. A simple explanation component to make the user know how the system arrived at a diagnosed disease.
5. User Interface for adequate communication between user and the system.

3.5.1 Expert System Shell

This Research design and development stage considered standard approach during system development since we couldnot implement using an expert system shell, effort was made to use the general structure of expert system shell like eMycin as a guide because it is more suitable to use eMycin in master research project due to its credibility and potential of acheiving convincing result. eMycin originated from the expert system mycin which diagnoses infectious diseases. Mycin's successful diagnostic results encouraged us to consider it as a guide. The builders of eMycin (Essential Mycin) stripped off the domain specific knowledge of Mycin and proposed the remaining structure as an expert system shell and also claimed its applicability for domains other than medicine, and this a very significant factor to consider because our proposed model for the expert system in also domain independent[14].

3.5.2 Prolog programming language

Prolog is a powerful logic programming language and programs in prolog consist of rules and facts,where each rule is equivalent to a Horn clause [15]. The entire set of facts and rules comprises the knowledge base. When this knowledge base is queried, the information which is a logical consequence of facts in the knowledge base can be retrieved. Inference is done in a top down fashion using the resolution principle [17]. prolog has a built in pattern-matching facility which is based on the unification principle [15]. Since the eMycin inference engine works on production rules, prolog's basic statements, which are rules, facilitate implementation of the rule based structure of eMycin. availability of different prolog implementations in different software encouraged us to work with prolog [18]. Also this increasing availability and its convenience to work with, enhances the portability of our work.

3.6 Expert system Algorithm

In view of our research approach, we have proposed a simple algorithm to diagnose selected medical disease and resolve any case of differential diagnosis if encountered.

Algorithm: Medical Expert System with Differential Diagnosis

1. Start the program
2. Collect the user data (Basic info) if provided otherwise go to step 9
3. Assert new rule to the working memory
4. Select the first distinct symptom of the next category of disease
5. ask if user has the symptom, while response is positive continue to next symptom of the disease other wise go to step 4
6. Repeat step 5 until all the symptoms of a disease is affirmed
7. Return the disease as goal state.
8. retract previously asserted rule.
9. terminate the program

Pseudocode for DD Medical Expert System

```
when
    confirmed
        all symptoms of a disease
    when
        no other disease with same symptoms exist
        then
            confirm person has that disease
        else
            use additionally asserted rules to decide
else
    when
        disease remain in knowledge base
        go to next Disease category
    else
        return "disease not in Knowledge base"
```

3.7 System Diagrams

To ensure efficient capture of different aspects of this research work, some relevant UML diagrams were designed clearly explain some important relationships between different components of our system. These diagrams are designed under the guidance of our proposed algorithm.

3.7.1 System Model

The project model provides an overview of the system showing how the general architecture are interlinked. The below figure shows the interaction between a user and our expert system software through a user interface provided by a computer. The software is well connected to prolog inferential engine which collects detail information provided by the knowledge engineer to the explanation module. The knowledge engineer collects facts from a domain expert and organize it into a suitable structure before adding it to the knowledge-base through the system back end (developer interface).

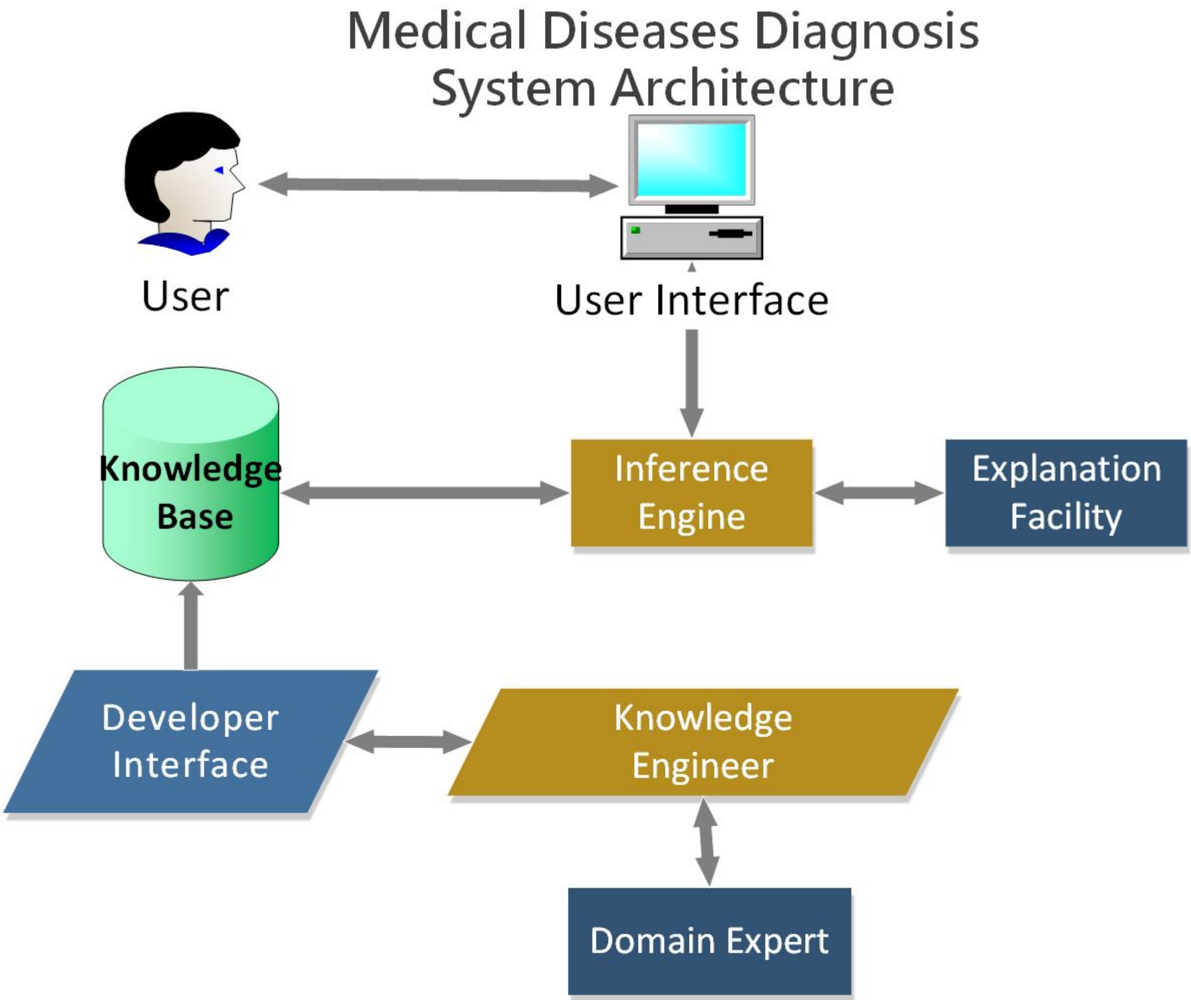


Figure 3.1: Expert System Model

3.7.2 System Process Diagram

The process diagram enable use describe the step-by-step flow of activities that occur in the system. The figure 3.2 below shows system Process Diagram. The diagnosis begins at the start point and proceed to a decision point of whether a user meets requirement because the system only proceeds if user provide required information like name and age etc. The following activity is series of questions from knowledge base to help decide if the disease a user is trying to diagnose is contained in the knowledge-base, the system terminates if it is not, but further determine if the diagnose disease is leading to a multiple result. The system uses rules to ascertain that the correct disease and return feedback to user to conclude that the a user have a particular disease

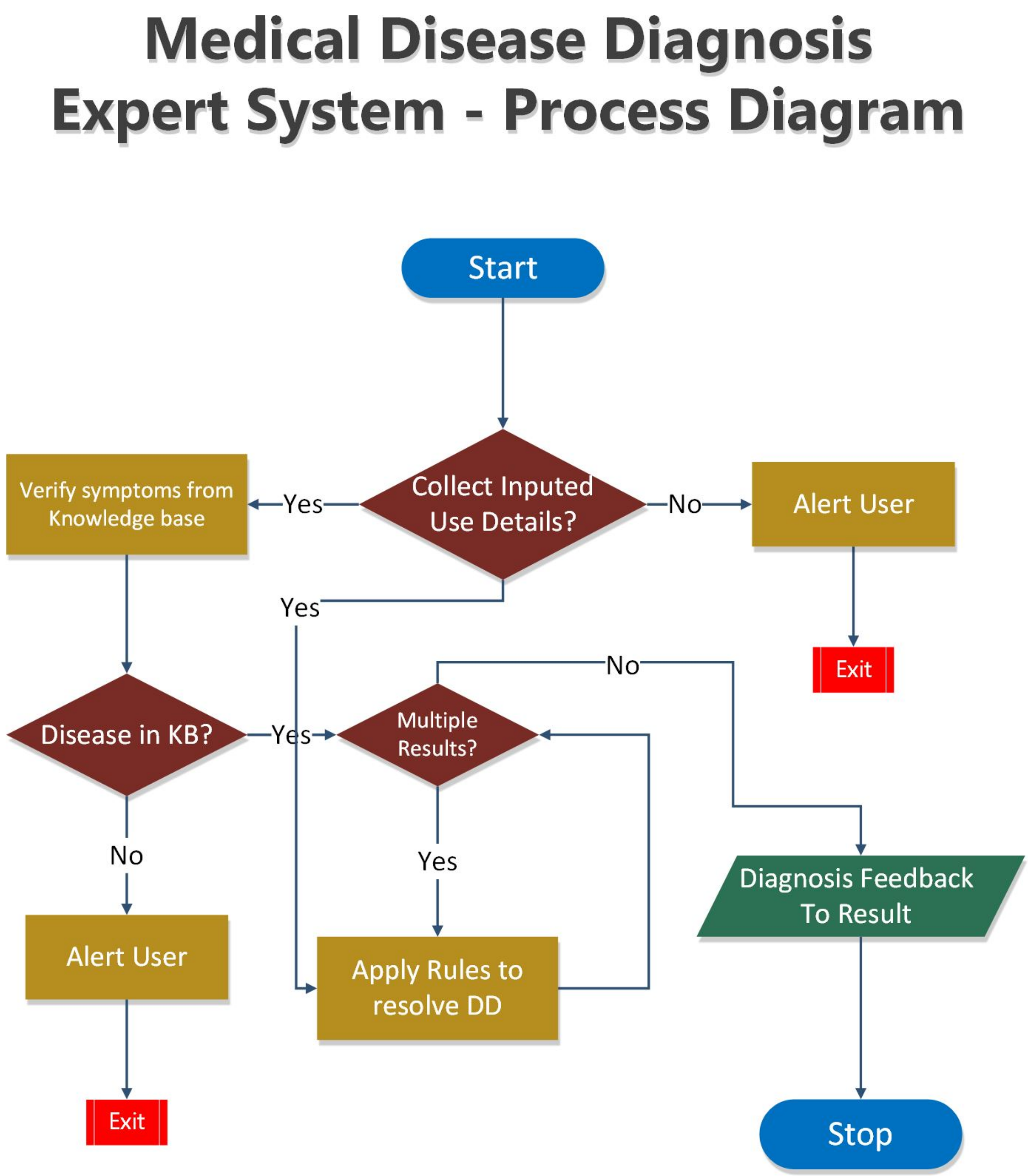


Figure 3.2: System Process Diagram

3.7.3 System Use-case Diagram

This diagram ensure that different actors that interact with the system is well captured. The below figure 3.3 shows how a user interact with the system, user inputs to the system, information retrieval from knowledge-base, flow of facts from domain expert to knowledge engineer for proper storage in the knowledge-base and feedback from the system back-end to the user are properly represented.

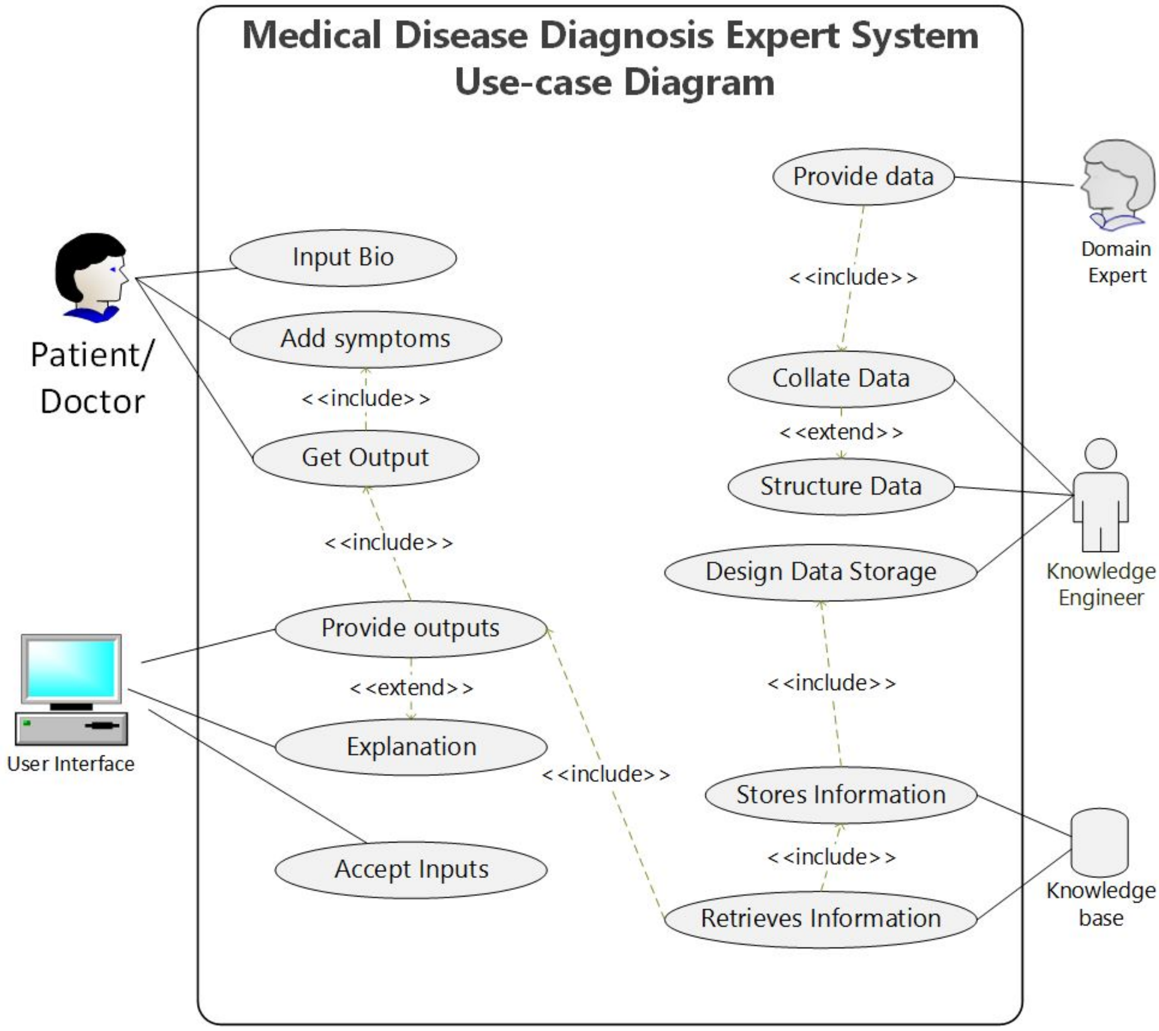


Figure 3.3: System Use-case Diagram

3.8 Java Prolog Interface(JPL)

JPL is a library using the SWI-Prolog foreign interface and the Java jpl interface providing a bidirectional interface between Java and Prolog that can be used to insert prolog code into Java as well as for embedding Java codes into Prolog. In both setups it provides a re-entrant bidirectional interface which make is convenient and flexible.

3.9 Domain Knowledge Data Collection

To ensure accurate data for building our knowledge base, we consulted 2 practicing medical doctor for domain data collection. the data collected from Human Medical Doctor was structure and made provided to the system in usable format to the expert system. The process we adapted during the domain data collection is represented in the figure below 3.4.

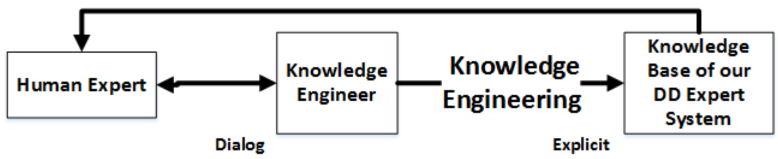


Figure 3.4: Domain Data collection process

3.10 Alternative Design Consideration

There are a number of alternative research setups which was not implemented because of resource limitation and time constraints. This was important because it gave us room to think outside the box for better solution.

3.11 Expert System Shell Approach

This approach aim to use a existing ES shell build the expert system with our knowledge base and extend it by attaching the differential diagnosis feature. The intended ES shell was prolog version of eMycin shell which would have provided the default ES shell flavor to our disease diagnosis system, but we were unable to implement this option.

Importance Using shell for building Expert system generally saves production time and ensure better chance of credibility.

3.12 Graph Problem Representation

The major aim of this approach was to enhance accuracy and we also believed that adding weight to the disease symptoms is better implemented using this approach.

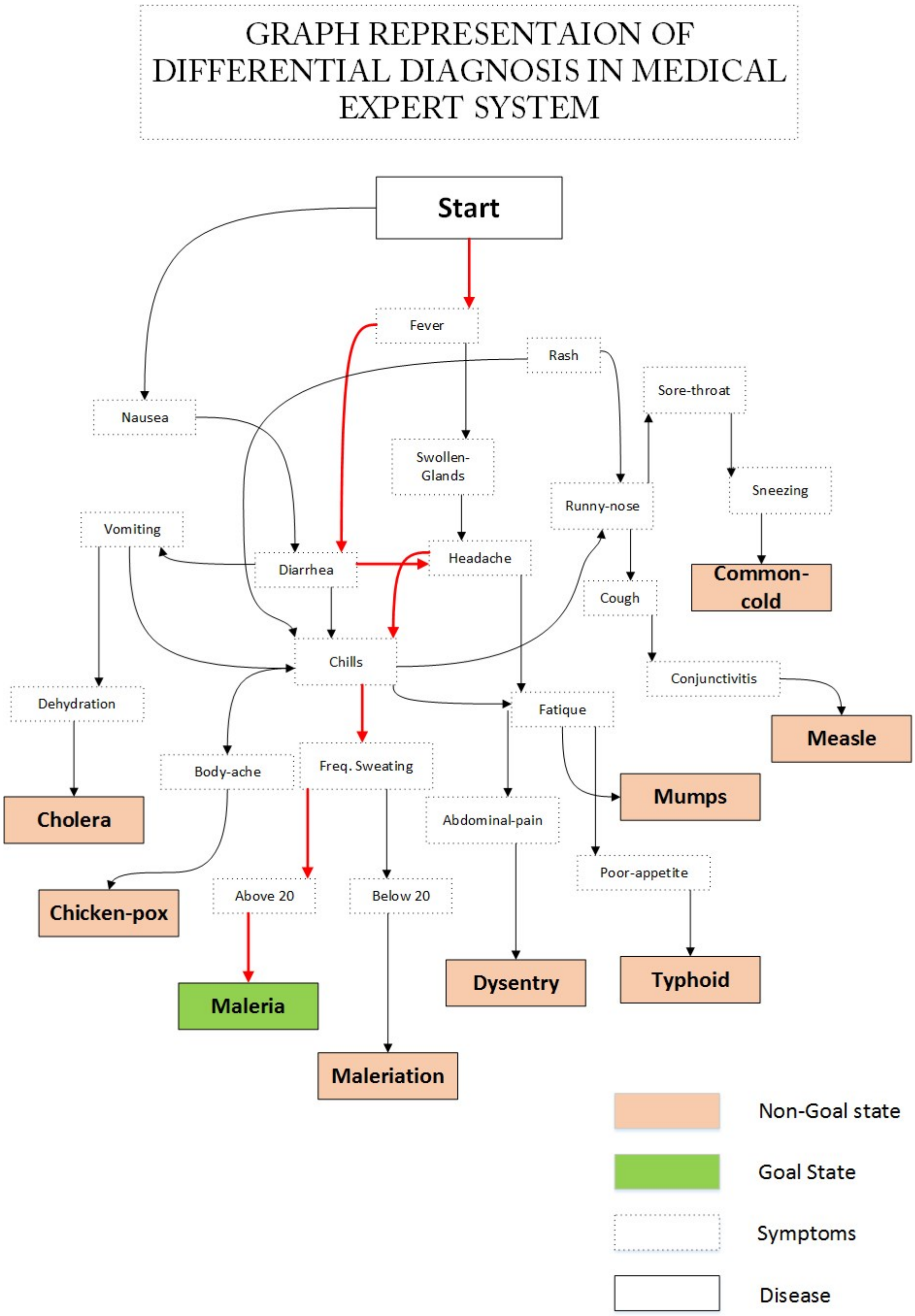


Figure 3.5: Graph representation of DD medical ES

Importance Graph representation of this problem provides a clearer analysis of the system with with better chance of getting significant research improvement since is not a usual method of representing the problem of differential disease diagnosis.

3.13 Summary

This Chapter provided the methodology of this research. Major system design approaches were discussed as well as the model of the software developed. This is mainly intended to provide clear understanding of how the problem solved in this study was designed and represented.

CHAPTER FOUR

Data Analysis and Discussion of Results

4.1 Introduction

This chapter discussed the system design considerations were implemented to ensure good result. Specific reasons for some of our approaches and how they can assist us meet our goals are explained in details. We also discussed valid evidences that this expert system work fine to achieve the desired goal. This was demonstrated by providing the expert system to random users for disease diagnosis. Data was collected to evaluate the system accuracy in disease diagnosis as well as its general user experience evaluation.

4.2 Disease Selection

The disease selection was base on commonness, high-occurrence-index and symptom related diseases. We have selected a few disease base on the these factors in order to ensure good and transparent result. The below listed disease and their respective symptoms are provided in our expert system knowledge base. System users are asked whether the have any of the symptoms in a sequential order.

Table 4.1: Selected Diseases for Diagnosis

	DISEASE DIAGNOSIS		
S/N	Disease	Cause	Contagious
1	Asbestosis	Bacterial	No
2	Asthma	Virus/Bacteria	No
3	Bronchiolitis	Virus/Bacteria	No
4	Cholera	Bacterial	Yes
5	Common cold	Virus	Yes
6	Chicken pox	Virus	Yes
7	Influenza	Virus	Yes
8	Maleria	Parasite	No
9	Measles	Virus	Yes
10	Mumps	Virus	Yes
11	Pertusis	Bacterial	Yes
12	Pneumoconiosis	Bacterial	No
13	Pneumonia	Bacterial/Fungi/Virus	No
14	Sarcoidosis	Bacterial	No
15	Tuberculosis	Bacterial	Yes
16	Typhoid	Bacterial	Yes

4.3 Disease Diagnosis Mechanism

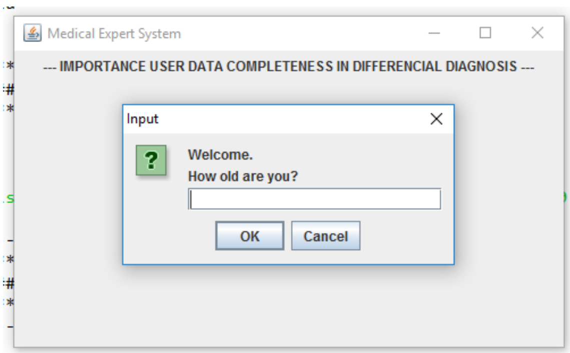
In this research we considered only locally common diseases The program works like this: the system used "yes" and "no" from our GUI user interface. if it has a positive answer to a symptom, it goes on with the symptoms from that disease. If only one symptom from the disease is negative it jumps to the first symptom from the next disease. Of course that in takes into accounts the category symptoms also. If at least one symptom from the disease category is negative, the program goes to the next disease. If all the category symptoms are affirmative, it goes on to the symptoms which make the difference between this disease and the other diseases from this category. Additionally Our system applies user imputed data like environment type and age to decided which rule to assert to the database this is a very crucial step because it is required to settle the case of differential diagnosis when all the symptoms could not differentiate between two or more diseases. Below is a highlight of our system components and what function they perform.

4.4 Probability Factor In Decision Making

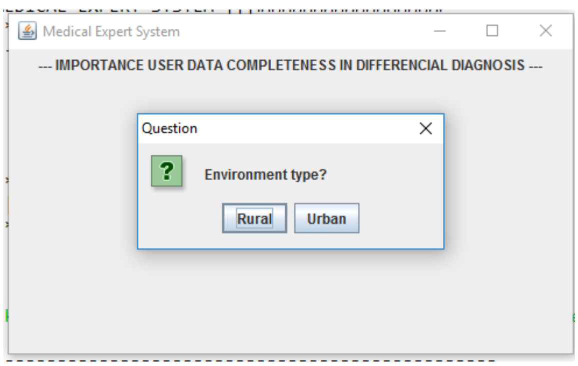
Probability factors are used by medical professional in real life but this aspect of diagnosis is never known to the user. Doctor may also recommend further laboratory test to confirm or rule out what may be concluded as the result of a diagnosis. To the user, there is minimum interest to know how or what probability a conclusion is based as far as it is correct. In this Research we consider a higher level probability, that is we made useful assumptions like since a rule declares that people under the age of 20 and above cannot get disease A but rather can get disease B if the symptoms are confirmed. when a user's age is greater or equal to 20, the probability for getting disease A is assumed to be zero and vise versa

4.5 Input & Output Screens

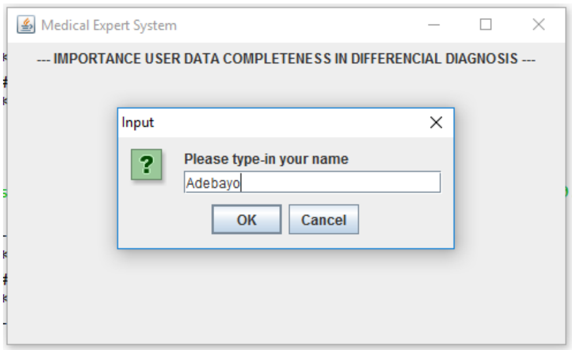
The figures below show system input and output screens through user interface.



(a) User age dialogue

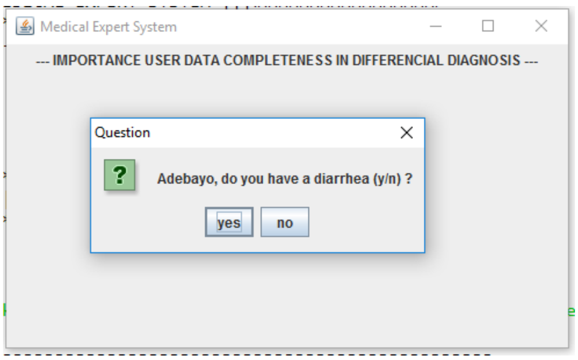


(b) User Environment dialogue

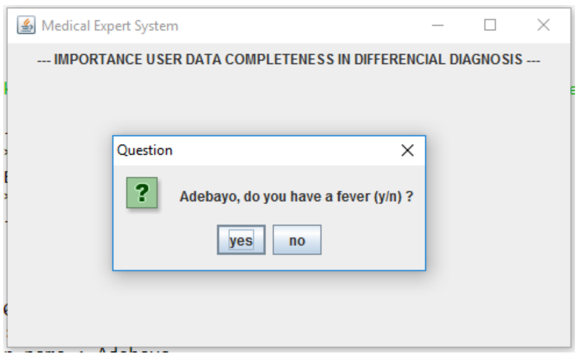


(c) User name dialogue

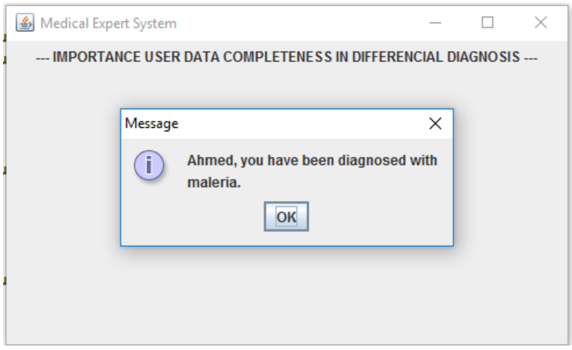
Figure 4.1: Display of User basic data input



(a) first symptom dialogue



(b) other user query from knowledge base



(c) User diagnosis feedback

Figure 4.2: Symptom dialog and system feedback to user.

4.6 Validity Test

The table below 4.2 shows the items considered during the evaluation of the validity of the system. It represents the degree at which our optimized expert system can diagnose patient disease correctly. The evaluation of our system is concluded to be right or wrong by the decision of the actual diagnosis which was carried our with all necessary medical diagnosis aids including laboratory test where applicable. Base of this consideration, 30 system users are provided this evaluation form to fill and result was generated base on the feed-back.

Table 4.2: System Validity Test

S/N		Decision after Diagnosis			Remark
	Patient	**Our Expert System**	**Human Expert**	**Actual Disease**	
1	A	Diseas-A	Disease-A	Disease-A	Right
2	B	Disease-X	Disease-B	Disease-X	Right
3	C	Disease-M	Disease-B	Disease-B	Wrong
4	D	Disease-N	Disease-P	Disease-P	Wrong

The pie chart 4.3 below shows a conclusive illustration of the general correctness of our expert system during medical diagnosis. This chart was generated from feed-back gotten form 30 system users.

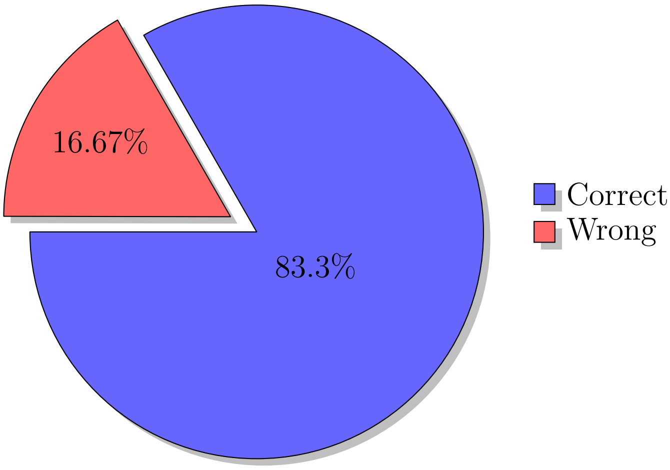


Figure 4.3: Pie chart of system validity test

4.7 Usability Test

The system usability table below 4.3 shows the graded point for each parameter considered in evaluating of usability of the expert system. The parameters were grader on the scale of 1-to-5, where 1 is the lowest and 5 is the highest. The resulting percentage for each parameter was computed base on the point assigned. an example of the calculation is shown below.

Bad = 1, Normal = 2, Good = 3, Very-good = 4, Excellent = 5; n=5

$\frac{x}{n} \star \frac{100}{1}$ e.g $\frac{2}{5} \star \frac{100}{1}$

Table 4.3: System Usability Test

S/N	Qualities	Remark
1	UI Friendliness	1-to-5
2	Error Avoidance	1-to-5
3	Resistance to Manipulation	1-to-5
4	Reliability	1-to-5
5	Portability	1-to-5

The bar chart below 4.4 shows a graphical illustration of the expert system usability test carried out. This chart was generated using data from 20 users of the expert system who filled the sample form show in table above 4.3 base on their personal observation.

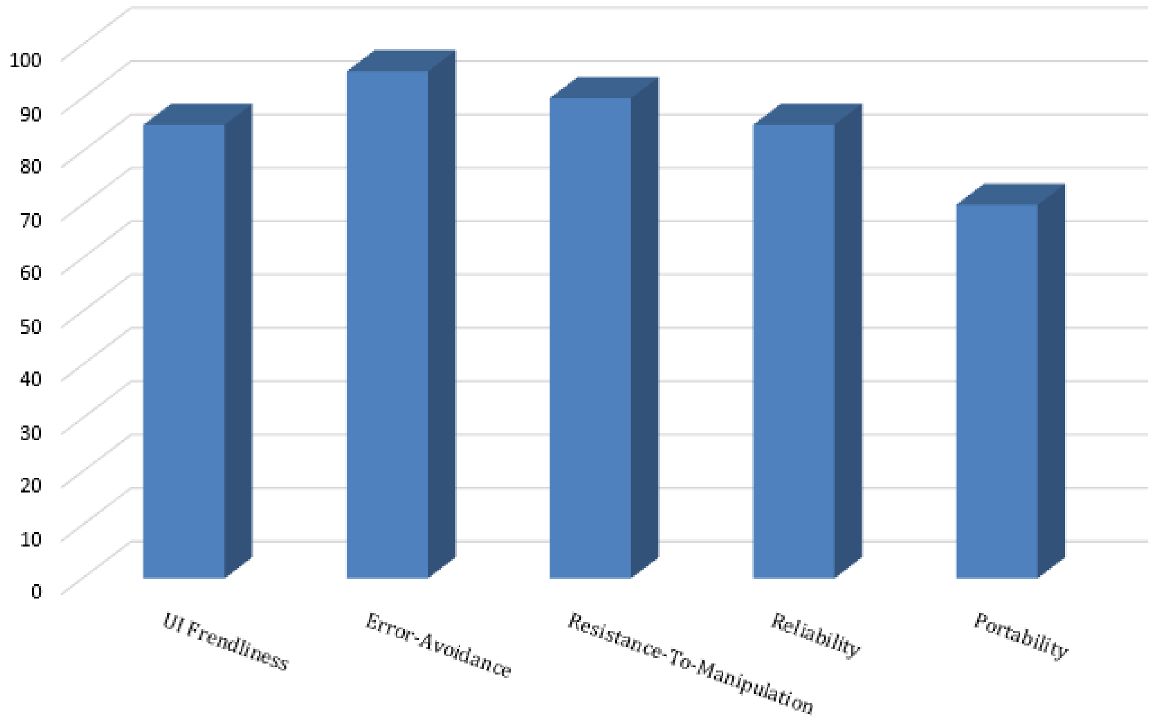


Figure 4.4: Bar Chart of Usability Test

4.8 User-System Sample Interaction

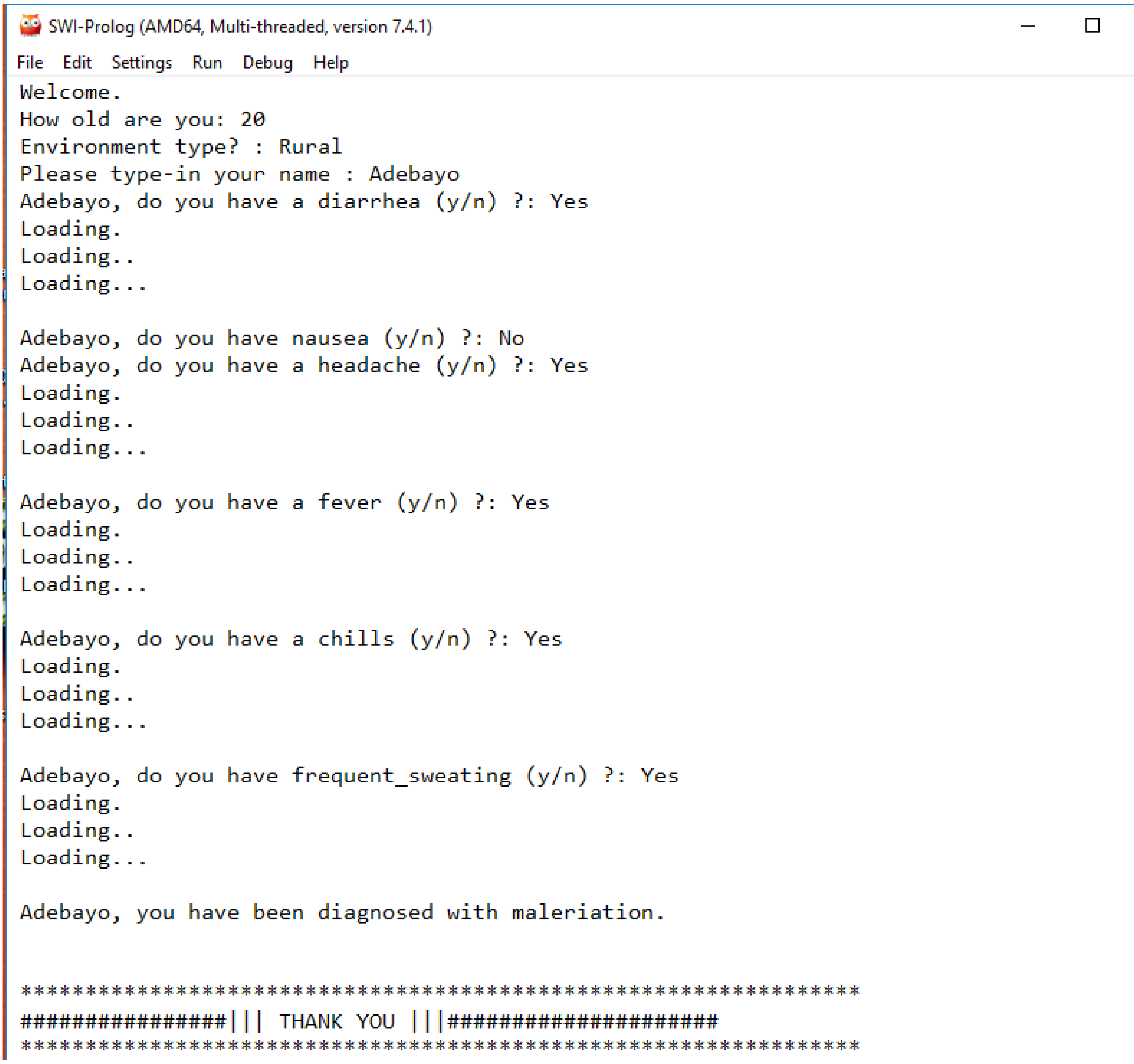


Figure 4.5: User-System Interaction during a disease diagnosis

4.9 Contribution of the Research

The major goal of this work was achieved by implementing the earlier proposed model using user added information to assert new rules which help to resolve DD. This approach of resolving differential diagnosis is very different from what other researchers have done and it works well in of field medical diagnosis and more importantly can be used in other domain where user input to the system is allowed.

4.10 Comments from Domain Expert

This research effort was implemented with the assistance of domain experts who provided first-hand information & guidance, however some relevant comments to consider when improving this work are provided below.

The weighted probability of some disease symptoms should be consider because, some disease symptoms may not always be seen in a patient even when they are affected by the disease.

This ES diagnosis is faced with a major challenge of differentiating between tropical disease. This is difficult and sometimes can hardly be correctly diagnosed even with the aid of medical laboratory tests because of their close similarity in signs & Symptoms. This problem can be solve by including other disease types from different categories like gastrointestinal diseases, metabolic disorder, hormonal diseases, respiratory diseases just to name a few.

The relevance of this work will be most likely considered if diagnosis is done with reference to laboratory test in cases where applicable.

This system can be enhanced by using non-technical nomenclature for symptoms in order to ensure that user understand the system query.

4.11 Summary

In this chapter, we discussed the technical procedures with relevant justification on how our system was implemented to ensure that target goal is reached. User input and output screens where also provided in order to justify whether user experience as well as error reduction mechanism are well considered. System evaluation form formats as well as the resulting charts was also provided in order to justify the relevance of this research and most importantly when compared with the work of other researches, our result analysis concludes that this work adapts a slightly different approach in medical disease diagnosis optimization.

CHAPTER FIVE

Summary, Conclusion and Recommendations

5.1 Summary

Medical expert system like *mycin* has evolved through optimization for better performance. This research effort explored a new approach to address accuracy issues with working mechanism of the current systems by proposing an enhanced model for medical expert systems capable of resolving differential diagnosis in order to guarantee the correctness of medical advice and service of physical medical doctor.

5.1.1 Challenges and Lessons Learned

General Prolog familiarity Substantial amount of time was taken to learn prolog in order to build an expert system from scratch. Familiarity only got better at later stage because of unlike other programming languages prolog is declarative.

Prolog eMycin-Shell As intended earlier, The use of ES shell was our preferred option for implementation of our approach to solve DD, but unfortunately, getting a prolog version of eMycin Shell proved difficult hence, pure programming language was adopted for implemented.

Weighted symptoms In an effort to improve precision by providing diagnose disease and computed probability, adding weight to symptoms was considered but this option was quiet difficult to implement. an alternative method considered shows promising evidence that weighted symptoms could be efficiently implemented.
From the above challenges, we have learnt that, our system may be efficient but undoubtedly other useful approaches exist. The initial intention to use a shell also lead us to closely observe the working mechanism of ES shell inferential engine, similar idea was considered during our system development.

5.2 Conclusion

There is a need for this improvement in medical diagnosis and it has become very crucial to address the problem of DD which is also a problem faced by most human doctors in medical field. It is obvious that, ES system proposed by other researchers so far does not utilize actual patient data like age and environment during the process of diagnosis. These factors can greatly affect the result of medical ES in completeness and precision irrespective of the model be it ES shell or pure programming language as in our case. Finally, our system has been design to serve patients in need of medical disease diagnosis, consultation software for Medical doctor and can be configured with other knowledge-base from any different field of interest.

5.3 Recommendations and Further Research Work

This system has a generality property and can be implemented to work in other domain. since the knowledge base can be changed to suit any domain.
This project can be improved to have better user interface. A full GUI enhances user experience and reduce possibility of error.

Weighted Probability For precision purposes, it is even more meaningful to inform a user of a medical doctor the percentage value at which the goal is considered based on computer probability. This approach tends to increase the credibility of diagnosis as well as the result.

Mobile software In order to enhance user experience and promote software portability, a mobile software of any platform (IOS, Android, Windows) can be developed using the same system model.This can further be linked to a human doctor for confirmation and medical prescription when a user is diagnose with a particular disease.

Image Input This system can be optimize to accept inputs not only as text but also images format for further analysis to diagnose if the image is infected with a particular disease or not. A good example is a situation where a user can input an image and the system determines whether the image is cancerous or not.

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Appendix A

Program Design, Algorithm mind map of Medical Expert System

Pseudocode for DD Medical Expert System

```
when
    confirmed
        all symptoms of a disease
    when
        no other disease with same symptoms exist
        then
            confirm person has that disease
        else
            use additionally asserted rules to decide
else
    when
        disease remain in knowledge base
        go to next Disease category
    else
        return "disease not in Knowledge base"
```

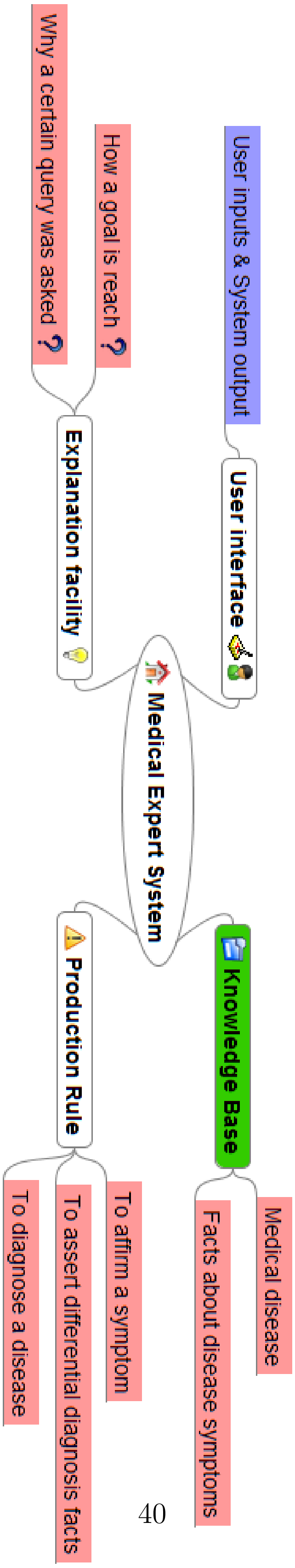

Figure 5.6: Expert System Mind Map

Appendix B

Prolog Program for Diagnosing Selected Diseases (Knowledge base)

```
hypothesis(Patient,cholera) :-
  environment,
  symptom(Patient,diarrhea),
  symptom(Patient,nausea),
  symptom(Patient,vomiting),
  symptom(Patient,dehydration).

hypothesis(Patient,maleria) :-
  cannot_have_maleriation,
  symptom(Patient,headache),
  symptom(Patient,fever),
  symptom(Patient,chills),
  symptom(Patient,diarrhea),
  symptom(Patient,frequent_sweating).

hypothesis(Patient,measles) :-
  symptom(Patient,fever),
  symptom(Patient,cough),
  symptom(Patient,conjunctivitis),
  symptom(Patient,runny_nose),
  symptom(Patient,rash).

hypothesis(Patient,dysentery) :-
  symptom(Patient,fever),
  symptom(Patient,chills),
  symptom(Patient,vomiting),
  symptom(Patient,diarrhea),
  symptom(Patient,fatigue),
   symptom(Patient,abdominal_pain).

hypothesis(Patient,maleriation) :-
  can_have_maleriation,
  symptom(Patient,headache),
  symptom(Patient,fever),
  symptom(Patient,chills),
  symptom(Patient,diarrhea),
  symptom(Patient,frequent_sweating).

hypothesis(Patient,typhoid) :-
  symptom(Patient,fever),
  symptom(Patient,poor_appetite),
  symptom(Patient,headache),
  symptom(Patient,diarrhea),
  symptom(Patient,fatigue).

hypothesis(Patient,pertusis):-
  symptom(Patient, runny_nose),
  symptom(Patient, sneezing),
  symptom(Patient, cough),
  symptom(Patient, mild_fever).

hypothesis(Patient,sarcoidosis):-
  symptom(Patient, dry_cough),
  symptom(Patient, shortness_of_breath),
```

```
 symptom(Patient, mild_chest_pain),
 symptom(Patient, scaly_rash),
 symptom(Patient, fever),
 symptom(Patient, red_bumps_on_legs),
 symptom(Patient, sore_eyes),
 symptom(Patient, swollen_ankles).

hypothesis(Patient,common_cold) :-
 symptom(Patient,headache),
 symptom(Patient,sneezing),
 symptom(Patient,sore_throat),
 symptom(Patient,runny_nose),
 symptom(Patient,chills).

hypothesis(Patient,mumps) :-
 symptom(Patient,fever),
 symptom(Patient,swollen_glands),
 symptom(Patient,fatigue),
 symptom(Patient,headache).

hypothesis(Patient,chicken_pox) :-
 symptom(Patient,fever),
 symptom(Patient,chills),
 symptom(Patient,body_ache),
 symptom(Patient,rash).

hypothesis(Patient,tuberculosis):-
 symptom(Patient, persistent_cough),
 symptom(Patient, fatigue),
 symptom(Patient, weight_loss),
 symptom(Patient, poor_appetite),
 symptom(Patient, fever),
 symptom(Patient, coughing_blood),
 symptom(Patient, frequent_sweating).

hypothesis(Patient,pneumonia):-
 symptom(Patient, cough),
 symptom(Patient, fever),
 symptom(Patient, chills),
 symptom(Patient, shortness_of_breath).

hypothesis(Patient,pneumoconiosis):-
 symptom(Patient,chronic_cough),
 symptom(Patient, wheezing),
 symptom(Patient,shortness_of_breath).

hypothesis(Patient,asbestosis):-
 symptom(Patient, chest_tightness),
 symptom(Patient, shortness_of_breath),
 symptom(Patient, chest_pain),
 symptom(Patient, lack_of_appetite).

hypothesis(Patient,asthma):-
 symptom(Patient, wheezing),
 symptom(Patient, cough),
 symptom(Patient, chest_tightness),
 symptom(Patient, shortness_of_breath).

hypothesis(Patient,bronchiolitis):-
 symptom(Patient, wheezing),
 symptom(Patient, fever),
 symptom(Patient, blue_skin),
 symptom(Patient, rapid_breath).

hypothesis(Patient,influenza):-
 symptom(Patient, headache),
 symptom(Patient, fever),
 symptom(Patient, chills),
 symptom(Patient, cough),
 symptom(Patient,conjunctivitis),
 symptom(Patient, nasal_congestion),
 symptom(Patient, runny_nose),
 symptom(Patient, sore_throat).
```