Honours Project Report

A Knowledge Based Expert System for Medical Advice provision

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	Category	Min	Max	Chosen
1	Requirement Analysis and Design	0	20	15
2	Theoretical Analysis	0	25	0
3	Experiment Design and Execution	0	20	10
4	System Development and Implementation	0	15	10
5	Results, Findings and Conclusion	10	20	10
6	Aim Formulation and Background Work	10	15	10
7	Quality of Report Writing and Presentation	10		10
8	Adherence to Project Proposal and Quality of Deliverables	10		10
9	Overall General Project Evaluation	0	10	5
Total marks		**80**		**80**

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Abstract

Many rural communities in South Africa have extremely limited access to medical advice. People travel long distances to clinics or medical facilities, and there is a shortage of medical experts in most of these facilities. This results in slow service, and patients end up waiting long hours without receiving any attention. Hence medical expert systems can play a significant role in such cases where medical experts are not readily available. This work presents the design of a knowledge-based expert system that aims to provide the patients with medical advice and basic knowledge on diabetes. JESS (Java Expert System Shell) is used as a tool for designing our knowledge-based expert system. A software evaluation of the expert system was carried out and positive feedback was received from users.

Keywords: diabetes, knowledge-based system, expert systems

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1. Introduction

1.1. Problem Outline

Diabetes mellitus is one of the most common chronic diseases in the world [1]. The International Diabetes Federation (IDF) estimated that there are 1.3 million people living with diabetes in South Africa. The IDF and the World Health Organisation predict that the numbers will double by 2030 [2,3]. Diabetes is fast becoming a major epidemic in South Africa. Recent surveys indicated that more than 80% of people with diabetes live in low and middle income countries [4, 5]. Research shows that many rural communities have extremely limited access to medical clinics. There is shortage of medical experts and medical facilities. This is the reason the statistics are higher in rural areas. However, diabetes mellitus is characterized by the raise of sugar levels in the blood. It can be caused by insufficient insulin and/or resistance to insulin. Though the disease cannot be cured completely, it can be well managed or controlled by healthy lifestyle choices. There is a need for the practical implementation of nutritional advice for people with diabetes.

1.2. Proposed System

The aim of this project is to develop a prototype knowledge-based system for the provision of medical advice on diabetes. A knowledge-based system is an expert system which is a computer program that emulates the decision making ability of a human expert. It acts in all respects like a human expert. It uses human knowledge to solve problems that would require human intelligence. The expert system represents expertise knowledge as rules and facts within the computer. These rules and facts can be used when needed to solve problems. However, a knowledge-based system captures the knowledge of a human expert and uses this knowledge to solve a real-world problem in real time. The knowledge-based system to be developed in this project is called a medical advisor system (MAS) and will be used to give advice to patients with diabetes. The MAS will also be used to give advice to people without diabetes to raise awareness of the disease.

1.3. Thesis Outline

According to our knowledge, no one designed knowledge based expert systems for the provision of advice on diabetes. In this work we will present the background chapter and the design chapter of an expert system for the provision of advice in diabetes using JESS. This paper has seven sections. The first three sections outline the background knowledge on expert systems and diabetes mellitus, the tools used to build an expert system and the mechanism used for knowledge acquisition. The other three chapters cover the design, implementation and evaluation of the system. The final chapter presents future work and concludes the report with findings of the system.

2. Background Chapter

The purpose of this chapter is to introduce the reader to some background information about expert systems and diabetes mellitus. This chapter consists of four sections. The first section gives an introduction to diabetes mellitus and its effect on the health of South African citizens. The second section outlines literature review on expert systems and knowledge based systems. The third section describes the application of expert systems in diabetes mellitus. The final section summarises some related work for both diabetes and medical expert systems.

2.1. Diabetes Mellitus

Diabetes mellitus is a clinical syndrome characterized by high blood sugar levels due to absolute deficiency of insulin. The lack of insulin affects the metabolism of the body. This causes an increase in the blood sugar levels because there is not enough insulin to reduce the percentage of glucose to its normal level. Insulin is a hormone produced by the beta cells in the pancreas, which helps to control the amount of glucose absorbed into the blood cells. In people with diabetes the beta cells either produce too little or no insulin [6]. Diabetes mellitus constitutes major risk factors and it is one of the major causes of deaths worldwide.

2.1.1. Types of diabetes

The main two types of diabetes according to World Health Organization (WHO) classification are Type I and Type II diabetes [1]. Type I diabetes is also known as juvenile diabetes or an insulin dependent diabetes mellitus. Type I diabetes mellitus occurs when the insulin-producing beta cells in the pancreas are damaged. Thus the pancreas does not produce insulin. This condition is most commonly diagnosed in people under the age of 30 [4]. However, type I diabetes can occur in older people as well due to destruction of pancreas by alcohol, disease or removal by surgery or progressive failure of pancreatic beta cells which produce insulin.

Type II diabetes is a progressive condition that occurs when the beta cells in the body are resistant to the effect of insulin. It develops gradually over a period of time but normally runs in families with a history of diabetes. The treatment of this condition usually begins with changes in diet and exercise since it is frequently associated with obesity. Research has shown that around 90% of people with diabetes suffer from type II diabetes [2, 3]. The probability of suffering from this type of diabetes is higher at older population group since it tends to occur in people older than 40 years of age [4].

2.1.2. Gestational diabetes

This type of diabetes affects about most females during last months of pregnancy. Gestational diabetes is normally associated with type II diabetes mellitus prevalence depending on the population group studied [7]. Studies have shown that women with Gestational diabetes mellitus are at risk of developing type II diabetes mellitus in the long term if the correct treatment is not practised at an early stage [8, 9]. Some women have very high levels of glucose in their blood, and their bodies are unable to produce enough insulin to transport all of the glucose into their cells, resulting in progressively rising levels of glucose. Pregnant women have enough insulin, but the effect of insulin is partially blocked by other hormones produced in the placenta during pregnancy [10]. Majority of gestational diabetes patients control their diabetes with exercise and a healthy diet. The disease normally disappears after pregnancy.

2.1.3. Pre-diabetes

Pre-diabetes is the pre-cursor of diabetes where the blood glucose levels are higher than normal but not high enough to be considered as diabetes [11]. The prevalence of pre-diabetes is about 25% between population groups older than 45 years [12]. About 70% of pre-diabetic patients are more likely to develop Type II diabetes and cardiovascular disease within 10 years [13]. However, if the condition is tackled at this stage through diet, exercise and other healthy lifestyle changes (weight management programme), the risk can be significantly reduced.

2.1.4. Causes and risk factors of diabetes

The cause of Type I diabetes is generally unknown but research has shown that genetic factors are important risk factors [14], coupled with an abnormal immune response [15]. Medical experts believe that Type II diabetes is caused by a combination of lifestyle and genetic factors. However, in some cases it can be caused by the following factors:

- sedentary lifestyle
- stress
- obesity
- advanced age
- unhealthy diet
- family history of diabetes
- improper functioning of the pancreas
- previously diagnosed with gestational diabetes

2.1.5. Symptoms of diabetes

The diabetes symptoms begin to appear when the glucose in the body is not used, but these symptoms fluctuate with the diabetes type. Type I diabetes symptoms are relatively observable, but Type II symptoms are sometimes not very apparent. Some of the main symptoms or warning signs of diabetes which are sometimes major origin of disability are [16, 17]:

- frequent urination,
- abnormal thirst,
- unexplained weight loss,
- Increased fatigue,
- extreme hunger, and
- blurry vision

Other common symptoms of diabetes include:

- tingling or numbness in the feet and hands,
- intermittent dizziness and loss of balance,
- unexplained aches and pains,
- frequent infections, and
- slow healing of cuts and wounds.

2.1.6. Complications of diabetes

Diabetes can cause severe complications in both short and long term. The short term complications are: hyperglycaemia, hypoglycaemia and diabetic ketoacidosis.

Hyperglycaemia is an effect of high blood sugar level. This condition occurs when a large amount of food is consumed and the body cannot use all the sugar [18]. Frequent urination, excessive thirst and nausea are the most common warning signs of hyperglycaemia.

Hypoglycaemia is a condition which results from low blood sugar levels. It can occur suddenly in people using insulin if too little food is eaten, if a meal is delayed or in the case of extreme exercise [19]. Symptoms include feeling cold, nervous, weak or hungry, and some people usually have headaches.

Diabetic ketoacidosis is a condition which develops from a severe shortage of insulin. This condition develops when insulin and blood sugar levels are out of balance such that ketones accumulate in the blood [20]. Symptoms include high blood sugar or ketones in the urine, dry mouth, and loss of appetite, fruity-smelling breath and possible vomiting.

Long term complications include:

- blindness,
- kidney failure,
- fungal diseases,
- cardiovascular diseases,
- Lower limb amputations

2.1.7. Diabetes treatment

There is no treatment for diabetes. However, it can be controlled by the following lifestyle changes:

- Meal planning
- Maintaining a healthy weight
- Exercise program
- Possible use of diabetes oral medication or insulin injections
- Monitoring of blood glucose level
- Stop smoking
- Moderate usage of alcohol
- Education about diabetes

2.2. Expert systems

Expert systems are developed from the study of artificial intelligence (AI), which is a branch of computer science aimed at transferring human intelligence into machines [21]. In AI, an expert system is an intelligent computer program that aims to use task-specific knowledge and inference techniques to solve problems at the level of a human expert [22]. It imitates the decision making ability of a human expert in a particular domain and can also give advices and explanations.

There are two types of expert systems: rule-based expert systems and knowledge-based expert systems. The main difference between these expert systems is the knowledge representation in the knowledge base [23]. The knowledge representation is more significant in expert system because the approach used to represent knowledge affects the development, efficiency, speed and the maintenance of the system [24].

2.2.1. Rule based expert system

The rule-based expert system has domain knowledge encoded in the form of rules from a human expert [25]. A rule is a conditional statement that links given conditions to actions [26]. In a rule-based expert system, a knowledge base is usually stored in terms of if-then rules which can be used to reach conclusions. A rule-based expert system is constructed based on an efficient algorithm called the Rete pattern matching algorithm [27]. This algorithm matches facts against the patterns in rules to determine which rules have had their conditions satisfied. Hence it uses a set of rules to analyse information about a specific class of problems and recommend one or more possible solutions [28].

2.2.2. Knowledge based expert system

The knowledge-based expert system encodes heuristics and rules into decision making framework [29]. A knowledge-based system uses artificial intelligence techniques in problem solving methods to support human decision making, learning, and action. The knowledge base of expert systems contains both factual and heuristic knowledge [30]. Factual knowledge is the knowledge that is widely shared, typically found in textbooks or journals, and commonly agreed upon by human experts in that particular domain [31]. Heuristic knowledge refers to an experiential, logical and judgmental knowledge used to speed up decision making [32]. Some applications applied by knowledge based expert systems are: medical treatment, waste management, production management, knowledge management, financial analysis, etc. [33].

2.2.3. Architecture of an expert system

Expert system consists of four major components which are: knowledge base, working memory, an inference engine and a user interface [34]. Figure 1 below represents the structure of an expert system.

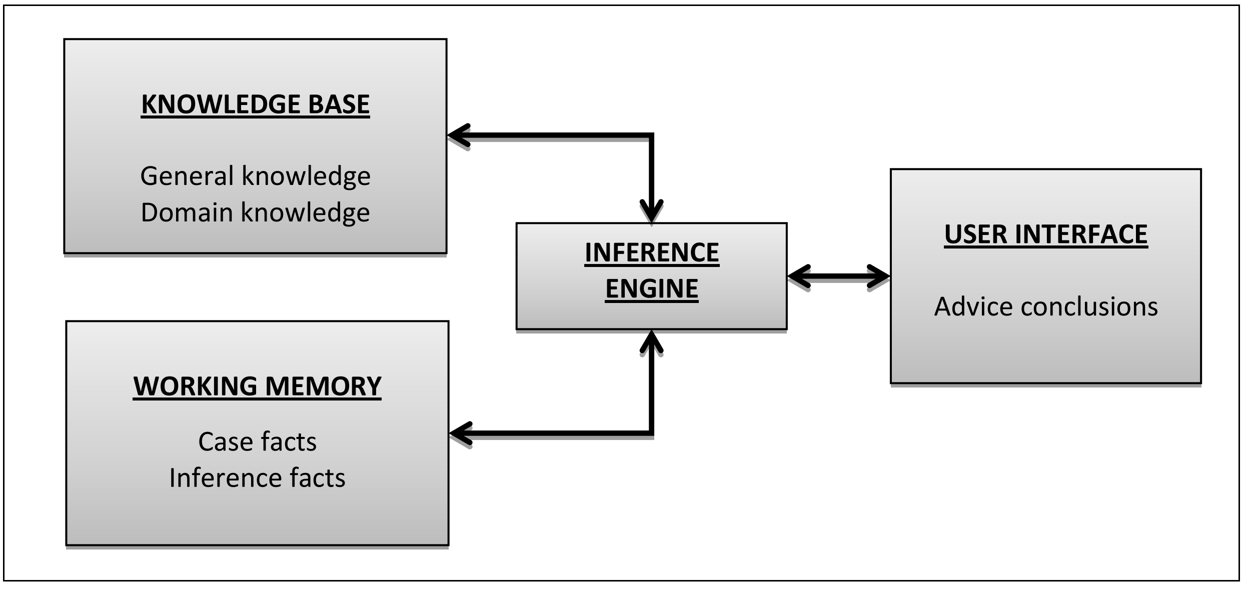


Figure 1: The structure of a knowledge-based expert system

- *Knowledge base*

A knowledge base is the heart of an expert system; it contains a collection of facts and rules which describe all the knowledge about the problem domain. Therefore, it stores all relevant information, data, rules, cases and relationships used by the expert system [35]. A knowledge base is not a database system.

- *Working memory*

Working memory is comparable to a relational database system. It contains information that is supplied by the end user. This information is used to evaluate antecedents in the knowledge base [36]. A change in the knowledge base results in creation of new values, thus the working memory will update its old values.

Inference engine

An inference engine implements the reasoning process of artificial intelligence; it is an analogy to human reasoning [37]. Its role is to work with the available data from the system and the user to derive a solution to the problem. The purpose of inference engine is to seek information and relationship from the knowledge base and to provide answers, predictions and suggestions in the way a human expert would. There are two kinds of inference engines: the backward chaining and forward chaining [38]. In backward chaining, the system first establishes a desired solution and works backwards to find facts that support the solution [39]. Backward chaining is goal-driven, thus it is used when the solution is known. In forward chaining the system first collects data which is used when the solution is known [40]. Forward chaining is data-driven; therefore it is used when the absolute solution is not known.

- *User Interface*

The user interface controls the dialog between the user and the system [41]. Thus, it is an intermediary that allows communication between the user and the system. The purpose of the user interface is to ease the usage of expert system by developers, users and administrators.

2.2.4. Benefits of using expert systems

Like many other traditional forms of software, an expert system offers benefits over human experts such as:

1. *Accessibility*- the knowledge of multiple human experts can be combined to give a more knowledgeable system than what a single person is likely to achieve. Expert systems are always available for use when human experts are not readily available.
2. *Consistency*- expert systems are less likely to contain inaccuracies provided the expert system has good knowledge representation. Inaccuracies or errors can be easily prevented.
3. *Time constraints*- many copies of an expert system can be made, but training new human experts is time-consuming and expensive.
4. *Stability*- it can assist a human expert in problem solving and is more likely to consider all possibilities.
5. An expert system can review all the transactions whereas a human expert can only review a sample.

2.2.5. Limitations of human experts

1. Human experts have more limitations over expert systems.
2. Human experts are unable to retain large amounts of data in memory.
3. Humans are unable to comprehend large amounts of data quickly.
4. Humans are slow in recalling information stored in memory.
5. Humans get tired from physical or mental workload.
6. Humans are subject to deliberate or unintentional bias in their actions.

Despite the aforementioned limitations, human expert also have benefits over expert systems. Human experts have common sense but expert systems do not have common sense yet. Human experts can respond creatively to unusual situations, expert systems cannot. Human experts automatically adapt to changing environments but expert systems must be explicitly updated. Expert systems are not good at recognizing when no answer exists or when the problem is outside their area of expertise. For this reason any output or advice from an expert system must be concluded and tested by a human expert.

2.2.6. Limitations of expert systems

Despite the aforementioned benefits, expert systems have certain limitations that impair their effectiveness in applying human-like decision making methods. Expert systems are knowledge dependent therefore they are only as good as the knowledge stored into them. Therefore, the expertise of an expert system is limited to the knowledge domain that the system contains. A practical limitation of many expert systems today is lack of fundamental knowledge. That is, the expert systems do not really have an understanding of the underlying causes and effects in a system. Typical expert systems cannot generalize their knowledge by using analogy to reason about new situations the way people can.

The gathering of human expert knowledge can be time consuming and the output depends mostly on the knowledge engineering. Transferring the knowledge of experts into rules and facts is not simple, especially when the expert’s knowledge has never been systematically explored. There may be inconsistencies, ambiguities, duplications or other problems with the expert's knowledge. Hence the problem of transferring human knowledge into an expert system is a major task.

2.3. Related Work

Expert systems are extensively used as a diagnostic tool in the medical industry. In fact, MYCIN is one of the first rule based medical expert system. It was developed by Shortliffe at Stanford University in late 1970s [42]. MYCIN was designed to identify infectious blood diseases based on the patient‘s medical data provided and to suggest a prescription or recommend treatment. It uses backward chaining inference procedure. The knowledge base consisted of approximately 450 rules derived from human knowledge through extensive interviews. The main limitation of MYCIN was its incomplete knowledge base which does not cover a full spectrum of infectious diseases. This is mainly because executing a full spectrum knowledge base requires more computing power than most hospitals could afford at that time [43].

MYCIN was extended by several medical expert systems such as ONCOCIN and CADIAG-2. ONCOCIN used the same rule-based approach as MYCIN but it used a different inference engine. ONCOCIN uses the forward chaining inference engine to reason [44]. The main advantage of ONCOCIN over MYCIN is that it allows an interaction with previous information or historical data. Computer Aided Diagnostic (CADIAG-2) is a knowledge representation of fuzzy concepts for medical diagnosis. Its inference engine uses fuzzy set of theory based methods [45]. Similar to MYCIN, this expert system was designed to assist physicians during diagnosis. The main advantage of CADIAG-2 is its simplicity and has also been shown to give reasonable results with less error. The common weakness of the abovementioned diagnosis intelligent system is that it does not focus on several independent rules giving the same diagnosis with an equal certainty.

These medical expert systems can be very useful in places where there is lack of educational facilities. They can assist medical assistants or nurses diagnose patients in rural areas. Therefore these systems can improve the life of rural communities, especially for people living with diabetes mellitus.

Diabetes mellitus problem can be divided into four problems, namely the diagnosis of diabetes, the treatment of diabetes, diagnosis of diabetic complications and the treatment of diabetes complications. Diabetes management seems to be the one most suitable for expert system development from the main four components [46]. This is because the domain is not very difficult to understand, it requires heuristics and adequate knowledge. It requires cognitive and not physical skills and it does not require too much common sense. The human expert reasoning around diabetes management is not difficult to understand and can be easily used in expert systems.

Few expert systems have been developed for diabetes. However, these systems deal with diagnosis. One of these expert systems is DIABNET knowledge-based system which was developed to help medical experts with therapy planning in gestational diabetes [47]. DIABNET helps physicians to interpret the data. DIABNET helps patients with diet planning, insulin therapy adjustments and any schedule alterations. Similar to other expert systems, the drawback of DIABNET is that it sometimes gives patients risky advices which can induce danger to them. However, this risk could be managed by delaying decision until sufficient information is available on the patient's next visit.

The other intelligent diagnosis system for diabetes is LDA-ANFIS (Linear Discriminant Analysis (LDA) and Adaptive Network Based Fuzzy Inference System (ANFIS)). The first (LDA) phase of this system is used to separate feature variables between healthy and diabetic patients' data while the ANFIS is used as a second phase classifier where the healthy and diabetic patient's features obtained from the first phase are entered [48]. Figure below shows the general block flow diagram of a LDA-ANFIS diagnosis system for diabetes. This diagnosis system is found to give reasonable results in classifying the possible diabetes patients and could be used to help clinicians reach final decision regarding their patients.

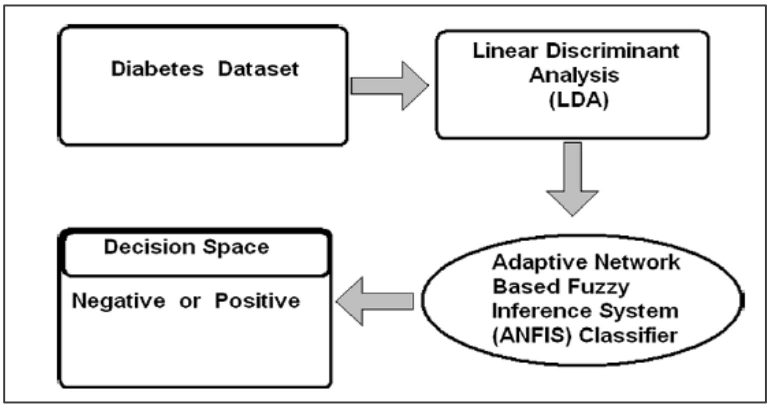


Figure 2: General block flow diagram of LDA-ANFIS intelligent diagnosis system [48].

Many web technologies have been used to help people manage diabetes. One of these systems is the SparkPeople system. SparkPeople is an online health service for advising patients on diabetes and other conditions. However, the system is not specific to different user. It gives advice to patients without looking at their current medical condition, exercise plans and healthy eating plan. The system provides the user with basic knowledge on diabetes mellitus and helps the user to manage their exercise and eating plans.

Figure 3: Spark People diet and fitness tracker service sample

2.4. Summary

The objective of this chapter was to review the literature in order to get a better understanding of the concepts involved in the development of an expert system. Most factors that need to be considered in expert system development were discussed, including all the advantages and disadvantages of using expert systems. The final section looked at some expert system designs that were used to help both patients and human medical experts to manage diabetes. The MAS system will be built considering both systems and other innovative ideas from human experts and different users.

3. Expert System Software Design

Software design is the first step in the development phase for any engineering system. Software design is an interactive process through which requirements are translated into a high level of abstraction for constructing the system. The high level concept is formerly represented as low level concept representation. The design must implement all of the explicit requirements. Therefore, the purpose of this chapter is to produce a representation of a system that will be built and to outline the methodology used to design the system.

This chapter consists of nine sections. The first two sections give a detailed description of the Medical Advisor System and the methodology that was used to design and implement the system. The next three sections outline the structure of the system, the programming tool that was used to implement the system and the knowledge that was put into the system. The last three sections outlines different iterations implemented including their design process, principles and concepts.

3.1. Description of the Medical Advisor System

Medical Advisor System (MAS) is a knowledge-based medical expert system prototype designed to give medical advice on diabetes. This system was designed using the JESS expert system programming language. The most challenging part was learning the language. The main part of building an expert system is the knowledge acquisition. For this project, most knowledge was obtained from a human expert, a medical doctor who is a diabetes specialist. This knowledge was converted into a knowledge base using a set of rules and facts. The rules in this system represent symptoms, risk factor and the actual advice. The advice provided by this system depends on the input given by the user. This system uses the forward chaining inference mechanism, instead of backward chaining. The reason of using this mechanism is because when dealing with diabetes, it is more important to collect information about the patient's condition first before making a decision. The forward chaining provides this competency. The system is designed as a menu based interactive system and the language is simplified for novice users to understand.

In addition, the system gives advice in between the consultation process, to avoid giving the overall advice at the end of the consultation. Research shows that people do not have patience to read a large amount of information at once. For this reason the advice is kept at minimal to avoid people missing valuable knowledge. The system gives some information for each symptom to the user during the consultation process and thus helps the user to gain more awareness about diabetes. This is an advantage over consulting a human because doctors do not normally have time to explain the reasoning to each patient. The last point is a summary of the main advices that a patient will need to take note of and to tell the patient whether or not to visit a clinic or to see a doctor. The advice is divided such that it considers the type of diabetes a patient has and other relevant information required to give appropriate advice to a patient. It is important to note that this system is not a substitute for physician and the system will not recommend treatment.

3.2. Design Methodology

Design methodology represents a notation and approach that is used to display real-time system characteristics. It contains a framework that is used to structure, plan and control the system. Figure 4 represents a hierarchical methodology that was used in the development of this expert system. This is different from the waterfall model. The programmer can go back to previous phases of the design at any phase.

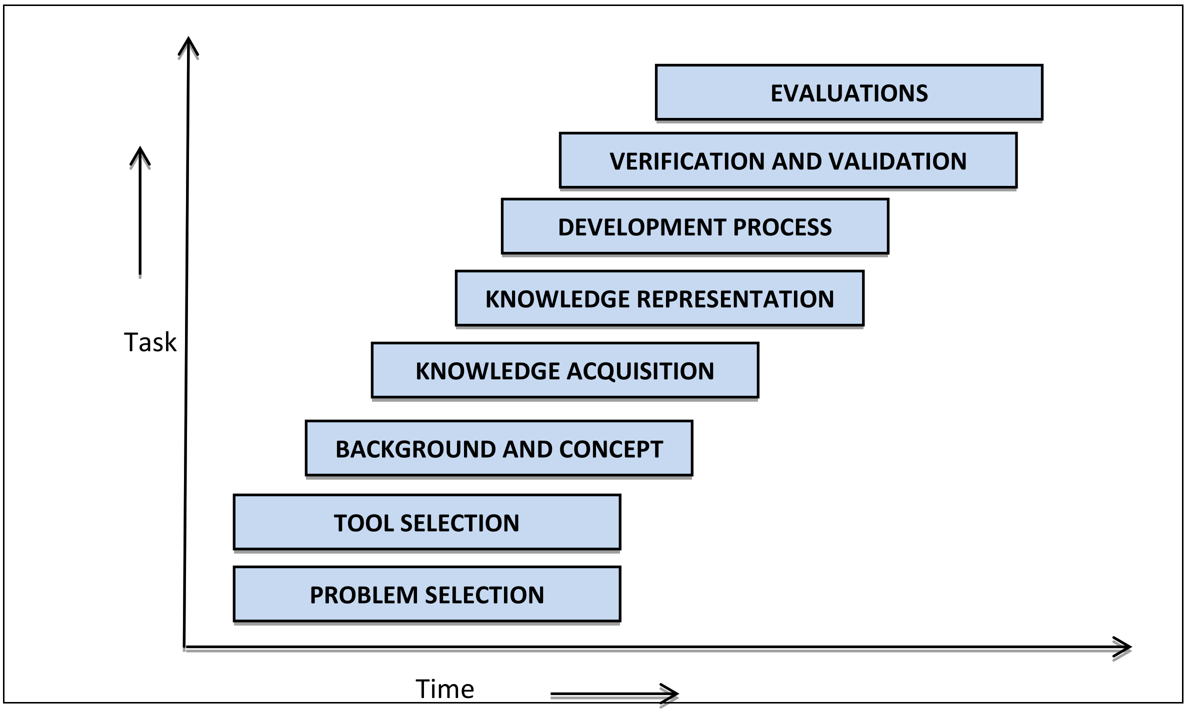


Figure 4: Hierarchy of the development of the medical advisor system

Problem selection:

Selecting an appropriate problem is essential in the development process. This is one of the general considerations that need to be considered before developing an expert system. There should be a clear identification of the problem. In order to have a clear understanding of what kind of an expert is required to do knowledge acquisition and who will be the users.

Tool selection:

Selecting a suitable tool depends on the anticipated requirements of the expert system to be developed. There are many tools for developing expert systems - there are programming languages, programming environments and expert system shells.

Background and Concept:

Doing a background study about expert system is essential before developing an expert system. The second essential part is to do a well study about expert system internal parts, how it works, rules, facts, inference methods and so forth.

Knowledge Acquisition:

Knowledge acquisition is the process of transferring the problem solving expertise from knowledge source to computer code.

Knowledge Representation:

Knowledge representation is a process of transferring the knowledge from a human expert to a knowledge base of an expert system.

Development Process:

The development process includes analysis, design, implementation and testing.

Verification and Validation:

The main purpose of verification is to check if the right system is developed. Validation checks if the system is developed according to the specifications.

Evaluations:

The main purpose of evaluation is to make conclusions about the developed program and to improve its effectiveness.

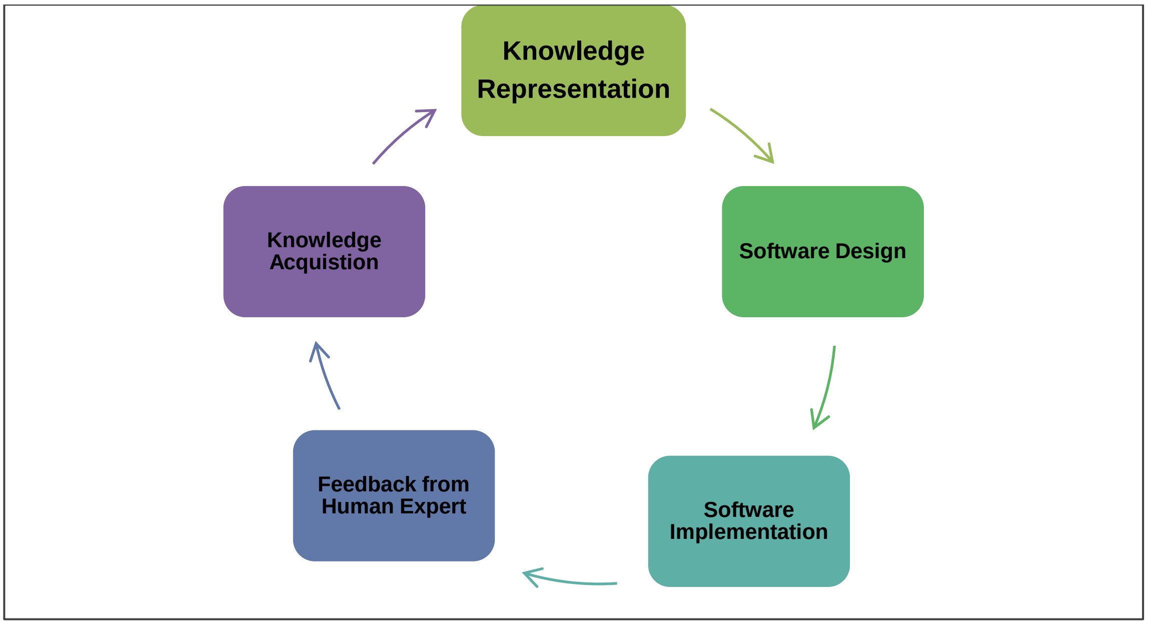


Figure 5: MAS process model

As mentioned, a waterfall model was not used in the development of this system. Figure 5 shows the process model that is used to develop the expert system. The difference between this process model and the waterfall model is the process flow. The process model illustrated above starts by collecting knowledge from a human expert and represents this knowledge accordingly. The next phase is about the design and implementation of the system. The last phase is to go back to the human expert and verify the knowledge or add more knowledge into the system.

3.3. System Architecture

The MAS design was influenced by a number of constraints, in order to be useful, the system had to be user friendly and had to provide consistently reliable advice to users. The system had to be able to use inexact or incomplete information to provide complete advice. Figure 6 represents the structure of the expert system. This diagram indicates all the main components that need to be implemented for MAS. This diagram illustrates all the expert system requirements and the requirements are as follows: human expert, knowledge engineer, interface developer and users.

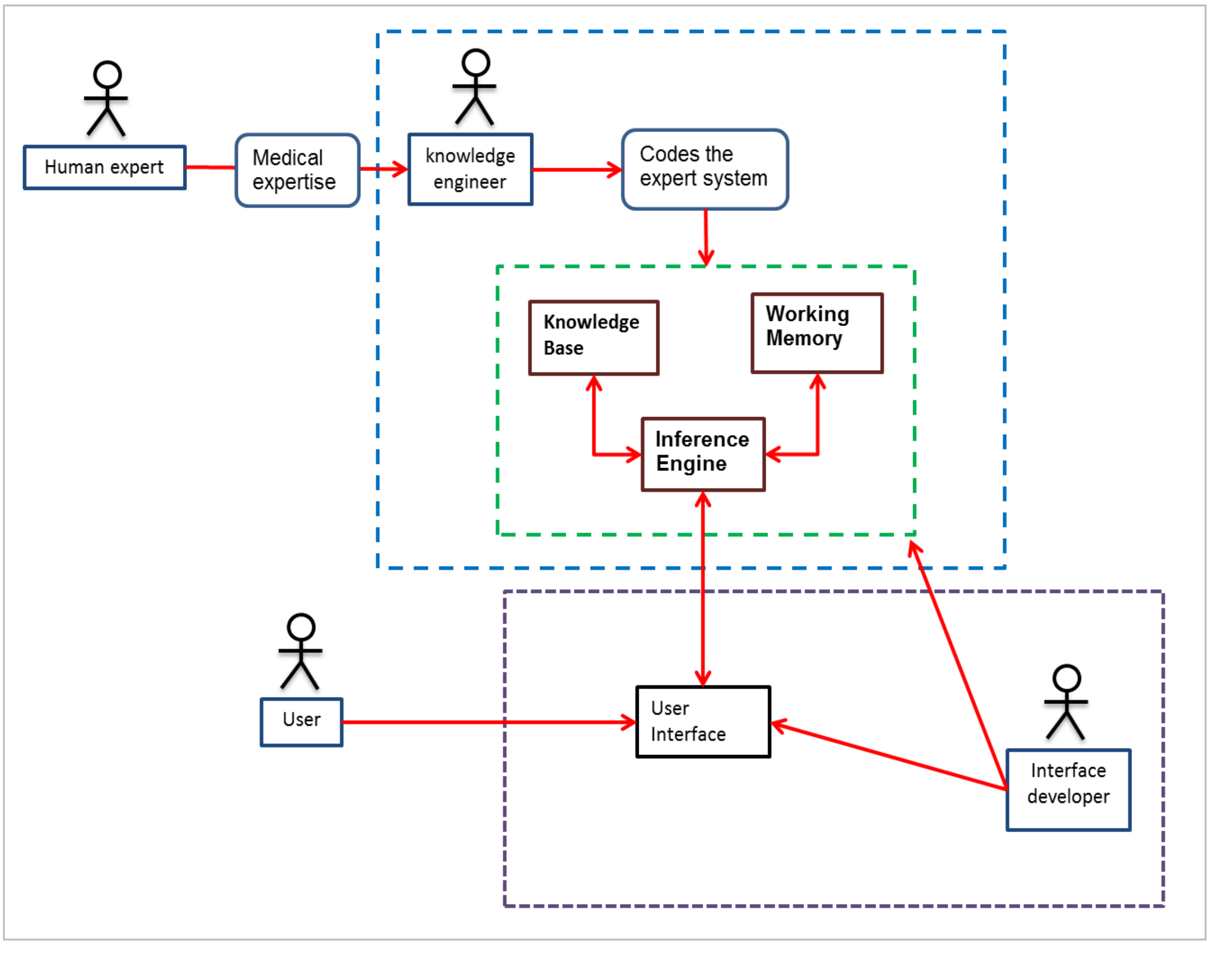


Figure 6: Medical Advisor System Architecture

3.4. Expert system building tools

Expert systems are usually written in special programming languages or tools. The most common available tools for the development of expert systems are shells. A shell is a piece of software which provides a development framework, containing the user interface, a format for declarative knowledge in the knowledge base and the inference engine. A shell simplifies the process of developing an expert system in a particular operating system kernel. Shells allow manipulation, accessing and modification of files. This paper will concentrate only on the two types of these shells, i.e. the CLIPS and the JESS expert system shell.

The major advantage of these languages, as compared to conventional programming languages is their simplicity of addition, elimination, or substitution of new rules and memory management capabilities. The primary functional difference between expert system language and procedural languages is the focus of representation.
Procedural languages focus on providing flexible and robust techniques to represent data such as arrays, linked lists, stacks, queues and so on, which is easy to create and manipulate. In contrast, expert system languages provide flexible and robust ways to represent data. Expert system languages specifically separate the data from the methods of manipulating the data. It allows two levels of abstraction, i.e. data abstraction (facts) and knowledge abstraction (rules).

3.4.1. C Language Production Integration System, CLIPS

CLIPS is a knowledge-based expert system shell originally developed at the National Aeronautics and Space Administration (NASA) for building expert systems. The origin of the CLIPS was in 1984 and is designed using C programming language. CLIPS is a productive development and delivery expert system tool which provides a complete environment for the construction of rule and facts for expert systems. Features such as an integrated editor and a debugging tool are included in CLIPS. CLIPS lacks a friendly graphical user interface, it uses the command-line based interface. It can be installed in any system that supports C compiler. However, CLIPS only supports three programming paradigms, i.e. rule-based, object-oriented, and procedural. Rule-based programming allows knowledge to be represented as "rules of thumb," which specify a set of actions to be performed for a given situation. Object-oriented programming allows complex systems to be modelled as modular components. The procedural programming capabilities provided by CLIPS are similar to capabilities found in languages such as C and Java.

3.4.2. Java Expert System Shell, JESS

JESS is a tool for building an expert system. JESS was written by Ernest J. Friedman-Hill at Sandia National Laboratories as part of an internal research project. The first version of JESS was written in late 1995, when Java was very new. A large number of JESS users contributed codes, suggestions, and patches in the JESS manual. The expert knowledge and the user inputs are stored as rules and facts in the knowledge engine. JESS uses Rete algorithm to match the rules and facts then these rules are executed to produce different results accordingly. JESS is available at no cost for academic use worldwide, with an appropriate license. JESS has many unique features including backwards chaining and working memory queries. JESS was originally conceived as a Java clone of CLIPS, but currently has many features that differentiate it from its parent.

JESS was chosen to implement MAS system mainly because JESS is implemented in Java, and it can be easily manipulated in Android platform. JESS can directly manipulate and reason about Java objects. JESS is also a powerful Java scripting environment, from which you can create Java objects, call Java methods, and implement Java interfaces without compiling any Java code. The version 7.2 is used in our system and the interactive command-line interface. JESS includes a full-featured development environment based on the Eclipse platform, shown in Figure 7 below. JESS is a rule engine for the Java platform. Therefore, to use JESS, you'll need a Java Virtual Machine. Its powerful scripting language gives you access to all of Java's APIs.

JESS expert system may be executed in three ways: interactively using a simple, text oriented, command prompt interface; interactively using a window/menu/mouse interface on certain machines, or as embedded expert system in which the programmer provides a main program and control execution of the expert system. In addition, a series of commands can be automatically read directly from a file when JESS is first started or as the result of the batch command. The JESS tool was downloaded for free from JESS website [49], the academic version is valid for a year (365 days).

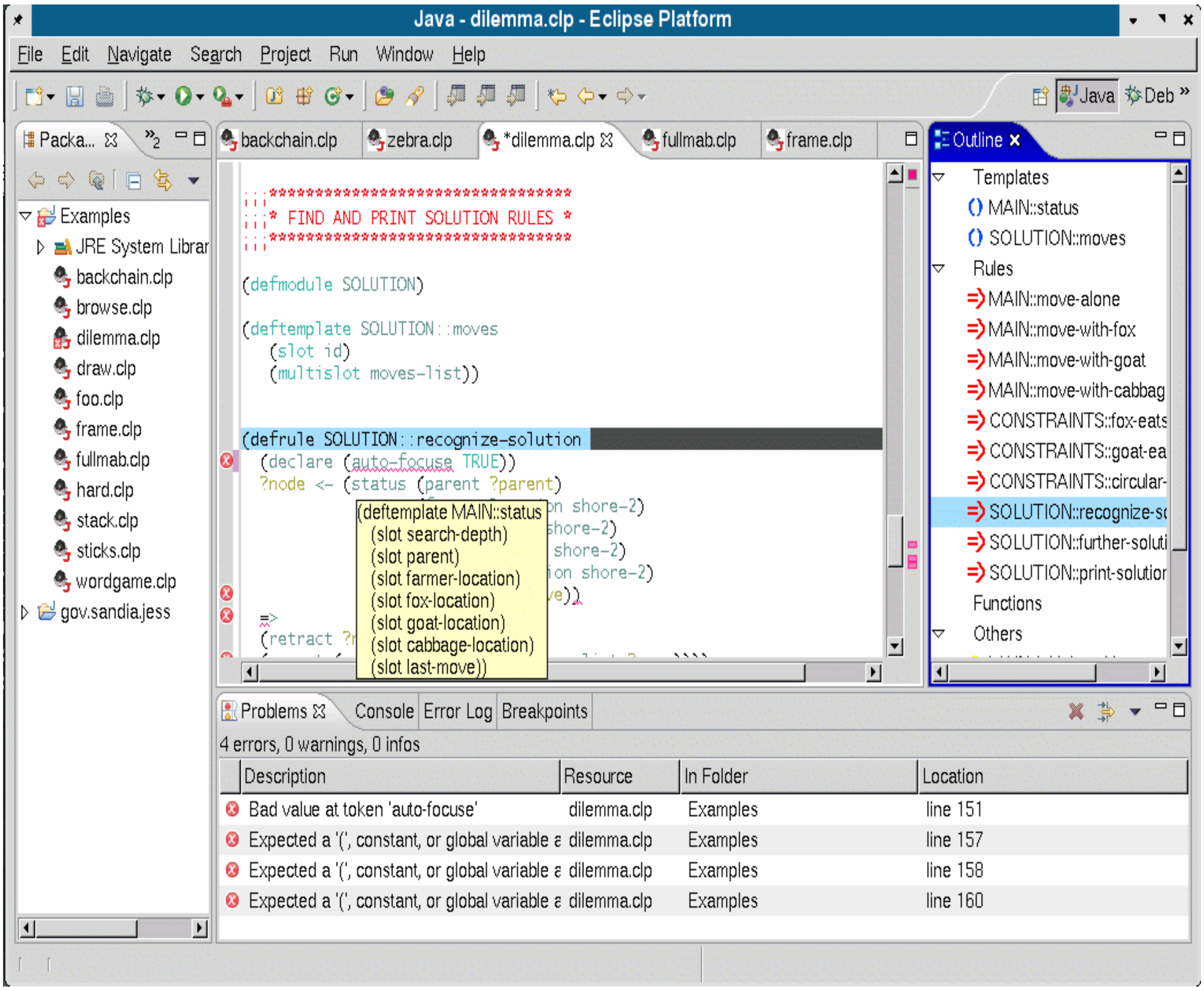


Figure 7: JESS Eclipse platform

Working with JESS

JESS interface is a simple, text-oriented, command prompt interface for high portability. The standard usage is to create or edit a knowledge base using any standard text editor. The primitive way of interacting with JESS is through command prompt. The interface provides commands for viewing the current state of the system, tracing execution, adding or removing information, and clearing JESS. Comments can be included in JESS code using semicolon. Everything from the semicolon until the next return character will be ignored by JESS.

The *shJESS* is a command used to start JESS (where sh stands for shell). JESS commands are always encased in brackets. Here is a list of some important commands:

(exit)	JESS shuts down
(clear)	Removes all rules and facts from memory or all constructs currently contained in JESS. Equivalent to shutting down and restarting the system.
(reset)	Removes facts information from memory (but not rules) and resets the agenda.
(run)	Starts executing a JESS program.

Figure 8: JESS commands table

JESS facts and rules

An expert system consists of rules as well as facts. Rules can be typed directly into JESS command prompt or loaded in from a file of rules created by an editor. Before rules created the deftemplate for the type of facts referred to by the rules must be defined. The general format of the rule is

(defrule<rule name>[<comment>]
<pattern> ;LHS of the rule
=>
<actions>); RHS of the rule

A rule may have multiple patterns and actions. The entire rule must be surrounded by parentheses and each of the pattern and actions also must be surrounded by parentheses.
The header of the rule consists of three parts. The rule must start with a defrule keyword, followed by the name of the rule. If the rule name already exist the new rule replace the old rule. The third part is an optional comment string. A comment is normally used to describe the purpose of the rule of any other information.

Facts are the first component of a JESS system and are made up of fields, which are symbols, strings, integers or floats. Facts are one of the basic high-level forms for representing information in JESS. The number of facts in the fact list and the amount of information that can be included in the fact is limited by the memory of computer. A fact is a piece of information such as (risk_factor non-smoking) or (symptom is-thirst) Facts are created by asserting them onto the fact database using the assert command .The assert command return a value called fact index.

JESS> (assert risk_factor non-smoking)
JESS> (assert symptom is-thirst)
JESS> (facts)
f-0 MAIN::risk_factor non-smoking
f-1 MAIN:: symptom is-thirst
For a total of 2 facts

The term “f-0” and “f-1” are called fact identifiers assigned to the facts by JESS and the integers following the letter f is called fact index. The facts command can be used to display the facts in the fact list. Facts can be deleted from fact data base by using retract JESS command

*JESS>**(retract 0)***
*JESS>**(facts)***
f-1 (risk_factor non-smoking)
For a total of 1 facts

The (retract 0) command above will delete f-0 fact from the fact data base. Facts are used to store a chunk of information.

Batch command

The batch command allows commands and responses that would normally have to be entered at the top level prompt, to read directly from a file. In JESS the commands and responses that must be entered to run a JESS program is stored as a batch file with extension .bat. When run under operating system that support command line arguments, JESS can automatically execute commands from a batch file on start-up. The syntax of batch command is *(batch <file-name>)*

3.5. Medical Knowledge Engineering

The purpose of this chapter is to outline the knowledge engineering process necessary to build an expert system. Building an expert system requires the computer programmer to have all the knowledge needed to solve the problem. There are two types of knowledge engineering: the broad and narrow perspective. The broad perspective involves the entire process of developing and maintaining intelligent systems whereas the narrow perspectives involve the following aspects:

- Knowledge acquisition
- Knowledge representation
- Knowledge validation
- Inference, explanation and maintenance

Figure 9 below shows a process of a narrow perspective knowledge engineering. The medical knowledge used in the system design is mostly the narrow perspective; the knowledge acquisition of the medical knowledge of specialized doctor is required for the development of an expert system. This knowledge will be used to setup rules for the knowledge base, an analogy of a relational database. These rules has an IF part that contain symptoms, risk factor sand other related parts. The THEN part recommends or provides advice that should be given to the patient. The following four sections outline what each aspect is and its importance in the narrow perspective knowledge engineering.

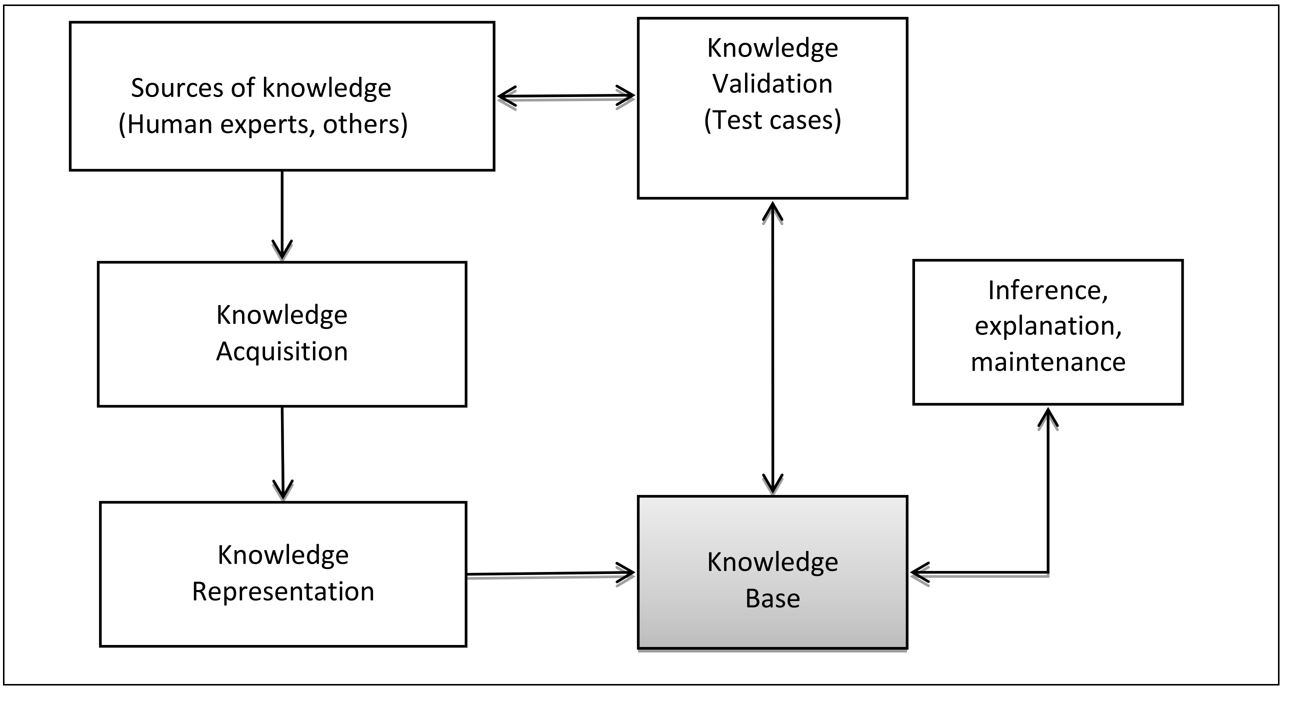


Figure 9: Process of Knowledge engineering

3.5.1. Knowledge Acquisition

Knowledge acquisition is the process of collecting knowledge from a domain expert before implementing the expert system. This aspect is the bottleneck in the development of a knowledge-based expert system. Different techniques for knowledge acquisition exist and each technique is suitable for a specific situation. The knowledge used in this system is from a human expert. There were variety of options to choose from such as books, the Internet and journals.

Although information is easily accessible over the Internet, it is not sequentially arranged, and the same applies to books. In addition, the experience that guides the reasoning of a human expert cannot all be found on in non-human sources such as books. Patients come with many variations of circumstances (e.g. other conditions that they have that interact with diabetes); a human expert is able to give all the relevant information with necessary precautions. The most important part of this aspect is the source of knowledge and the experience contained in it. There are many sources of knowledge such as books, internet and experts. Hence, the knowledge acquisition for this work was obtained through interviews with a diabetes human expert, diabetes type I and type II and other diseases. During the first meeting, a lot of diabetes basic knowledge was provided including symptoms, complications, and treatment and diagnosis procedures. For this system there was no need of meeting with the patients at an initial stage because the system does not do diagnosis.

Since the beginning of this project, I met with the endocrinologist once a week to discuss the knowledge concluded into the system and the manipulation of this knowledge. The main important part was also to look at all the cases that the system should consider. The endocrinologist's professional knowledge of the treatment and management of diabetes was the key to the success of this system. Figure 10 below is a sample of the knowledge obtained from the first meeting and this note is used in addition to a voice recording.

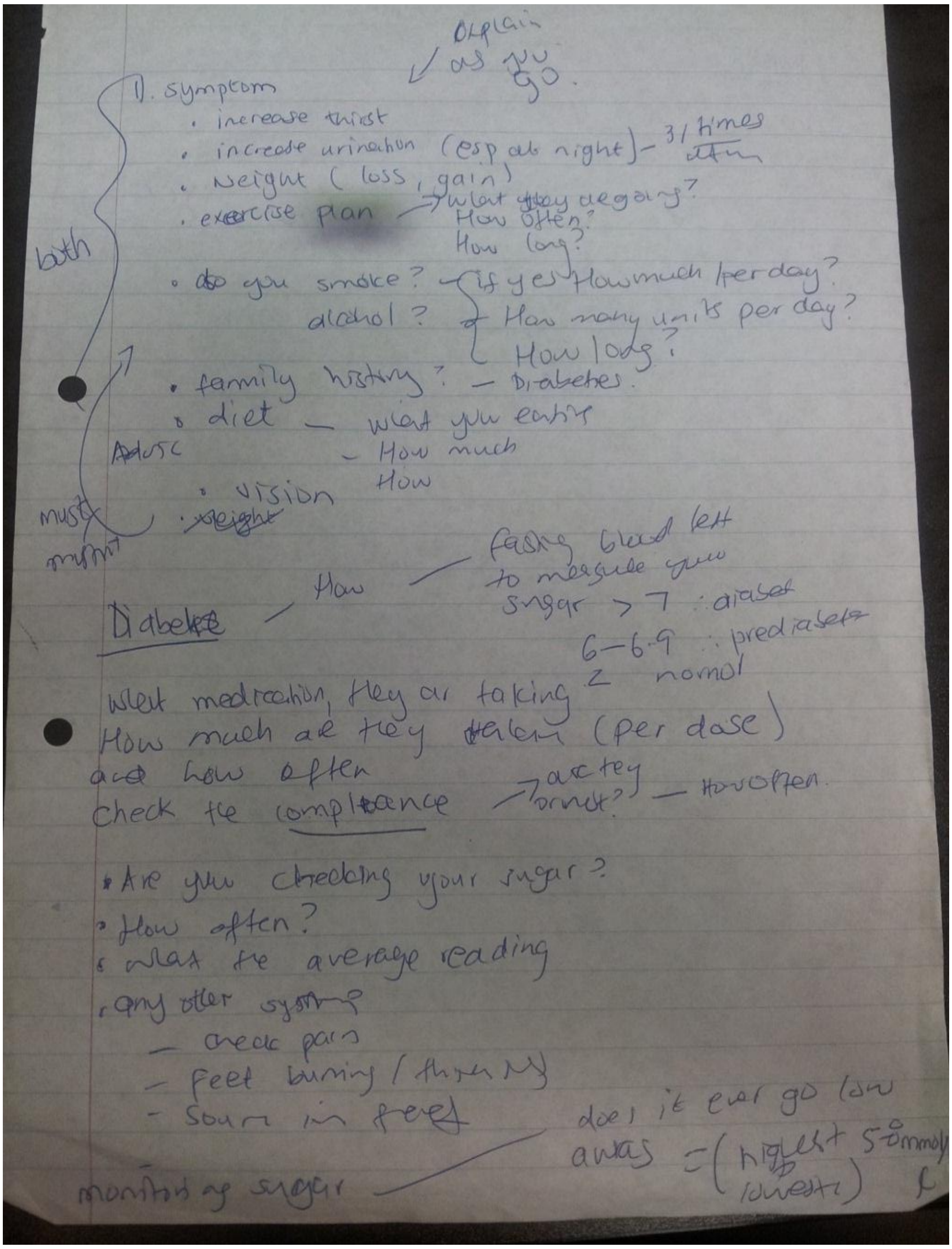


Figure 10: A summary of the knowledge obtained from the expert in the first interview

In the first meeting, more basic information about diabetes and the necessary knowledge needed to design the expert system was obtained.

3.5.2. Knowledge Representation

The knowledge representation aspect involves the organisation of acquired knowledge with the intention of making knowledge ready for use. For instance, a patient with diabetes will receive different advice from a patient without diabetes. Figure 11 below illustrates how knowledge was transferred from resources to the knowledge base of the expert system.

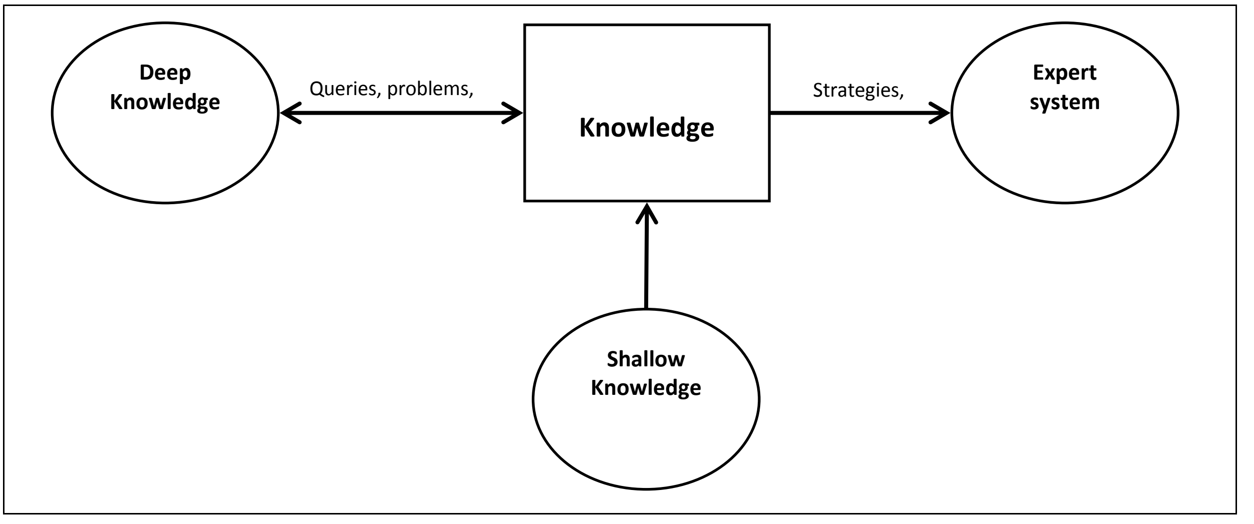


Figure 11: Transferring of knowledge from human expert to the expert system

Shallow knowledge is the representation of generally available information that can be used to deal with very specific situations. For example, if a patient has diabetes, they have diabetes symptoms so there is no point of asking them about the symptoms but rather ask about their type, medication and lifestyle plans. This knowledge can be shown as rules but the example below shows a simple rule: if patient has diabetes, then ask their diabetic type. This basically represents the input and output relationship of a system. It can be presented in terms of IF-THEN rules. Deep knowledge is the internal and fundamental structure of a system and involves the interactions between the system's components. Human problem solving is based on deep knowledge of a situation. Deep knowledge can be applied to different tasks and different situations. This is the knowledge obtained from human experts.

3.5.3. Knowledge validation

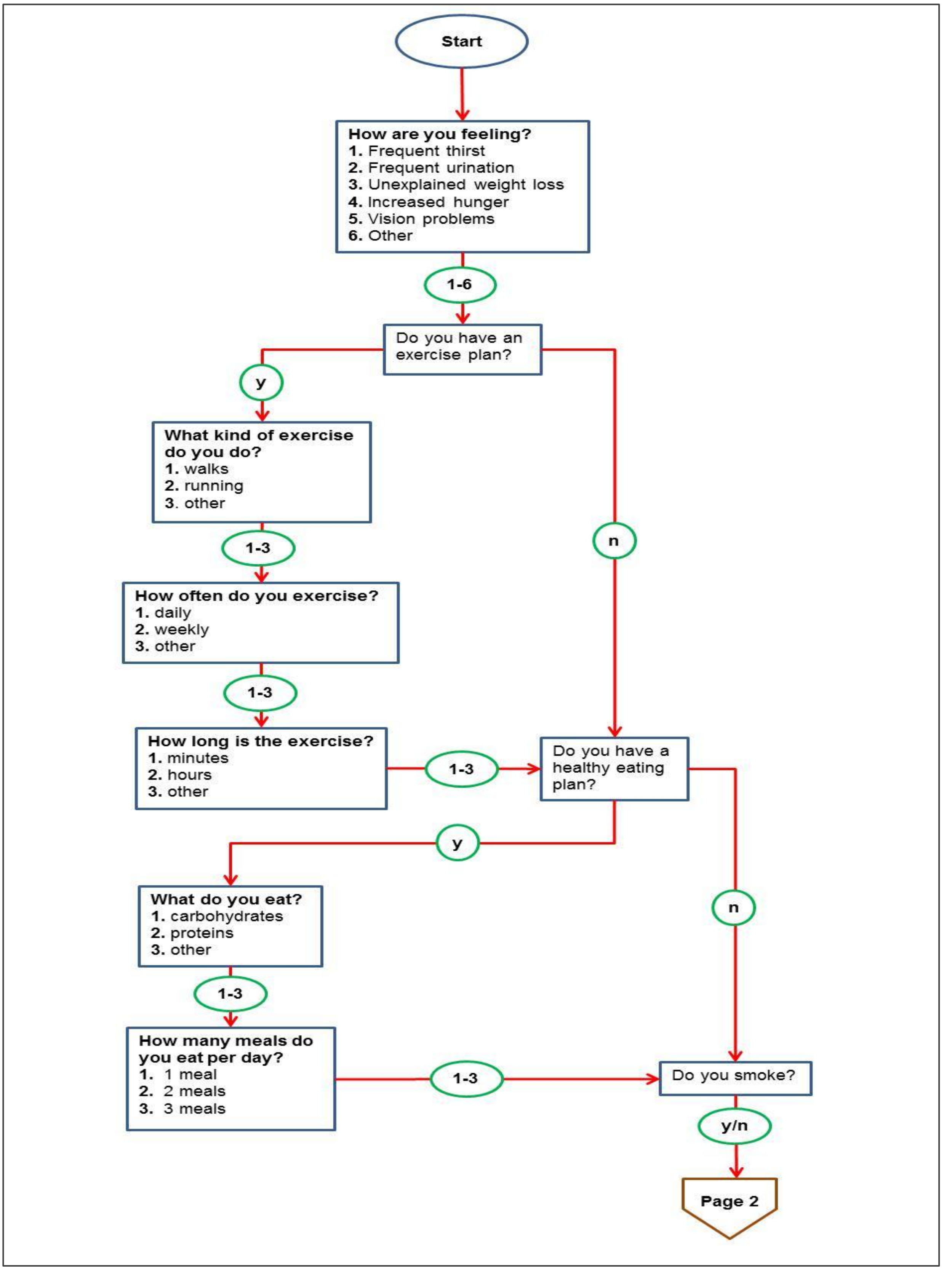
The knowledge validation phase involves validating and verifying the knowledge until the quality is acceptable. This is done by the use of test cases and the testing results are shown to the human expert to verify the accuracy of the system. More details on the validation aspect can be found in chapter 6.

3.5.4. Inference and maintenance

This phase involves the design of the system to reasoning on the stored knowledge. More details are added into the implementation chapter.

3.5.5. System Architecture

After the first meeting with the human expert, the first expert system prototype was designed. Figure 12 displays a flow diagram of this knowledge. This prototype was giving advice on exercise plan, eating plan and monitoring sugar level. The system firstly asks the patient about the symptoms or warning signs they are experiencing. The system only has two ways in which it can be terminated as shown in Figure 12.


Start
How are you feeling?
1. Frequent thirst
2. Frequent urination
3. Unexplained weight loss
4. Increased hunger
5. Vision problems
6. Other
1-6
Do you have an exercise plan?
y
What kind of exercise do you do?
1. walks
2. running
3. other
1-3
How often do you exercise?
1. daily
2. weekly
3. other
1-3
How long is the exercise?
1. minutes
2. hours
3. other
1-3
n
Do you have a healthy eating plan?
y
What do you eat?
1. carbohydrates
2. proteins
3. other
1-3
How many meals do you eat per day?
1. 1 meal
2. 2 meals
3. 3 meals
1-3
n
Do you smoke?
y/n
Page 2

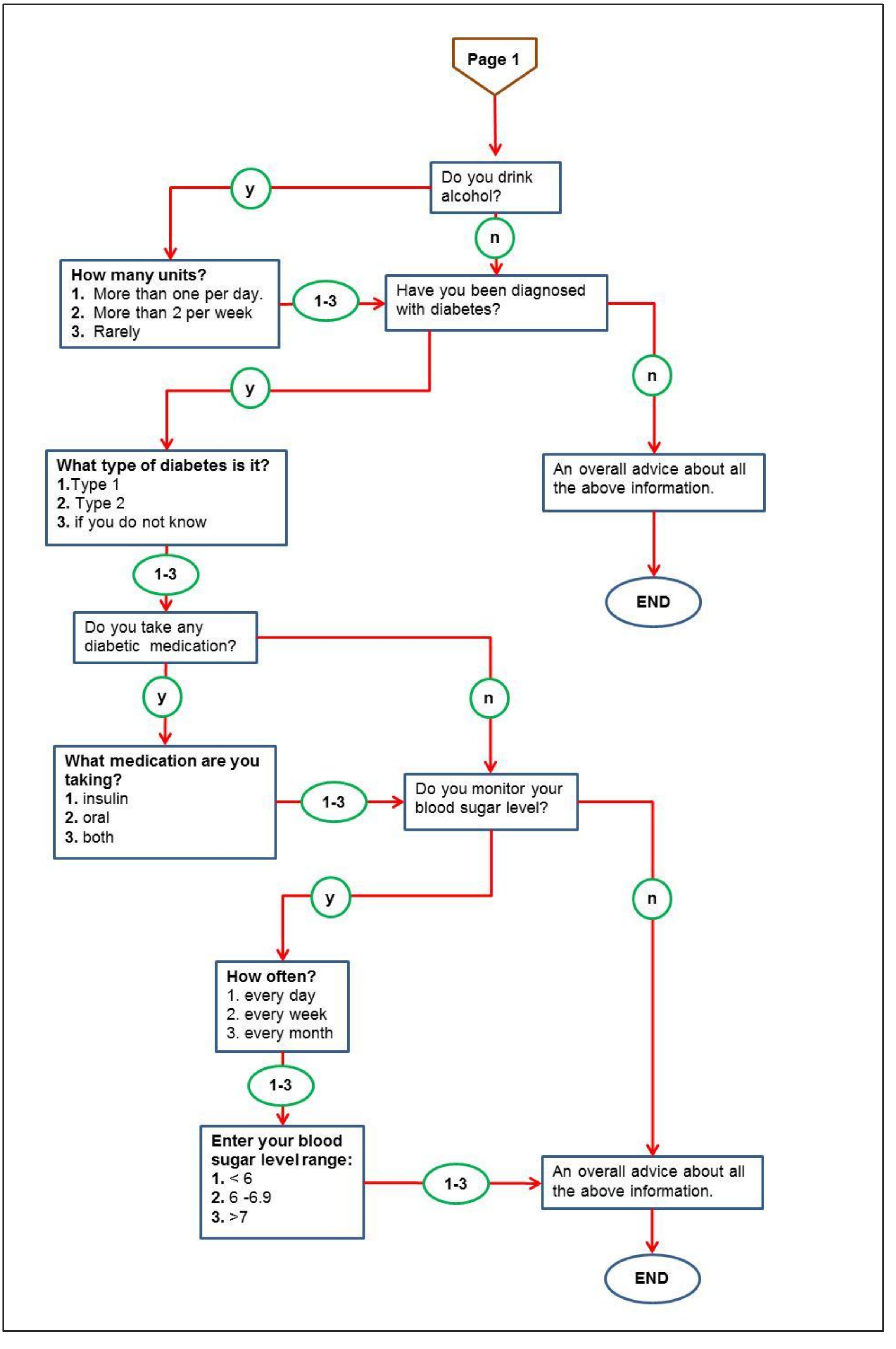


Figure 12: The initial MAS expert system prototype flow diagram

3.5.6. Findings and recommendations

Not including the above prototype, four more prototypes were designed. All of these prototypes had a few problems. Here is a list of the most relevant issues raised in the second meeting:

- The system was not able to consider all the aspects
- Advice was only provided at the end of the system
- The system was not giving enough advice to the patients
- The language used was not simple for people in rural areas
- Asking unnecessary information that was never used in the advising process
- The assumptions that were made in the system such as assuming that only people with diabetes will use the system. This assumption was removed in the final system, new assumptions were made
- Figure 13 shows the information that was used to improve the first prototype.

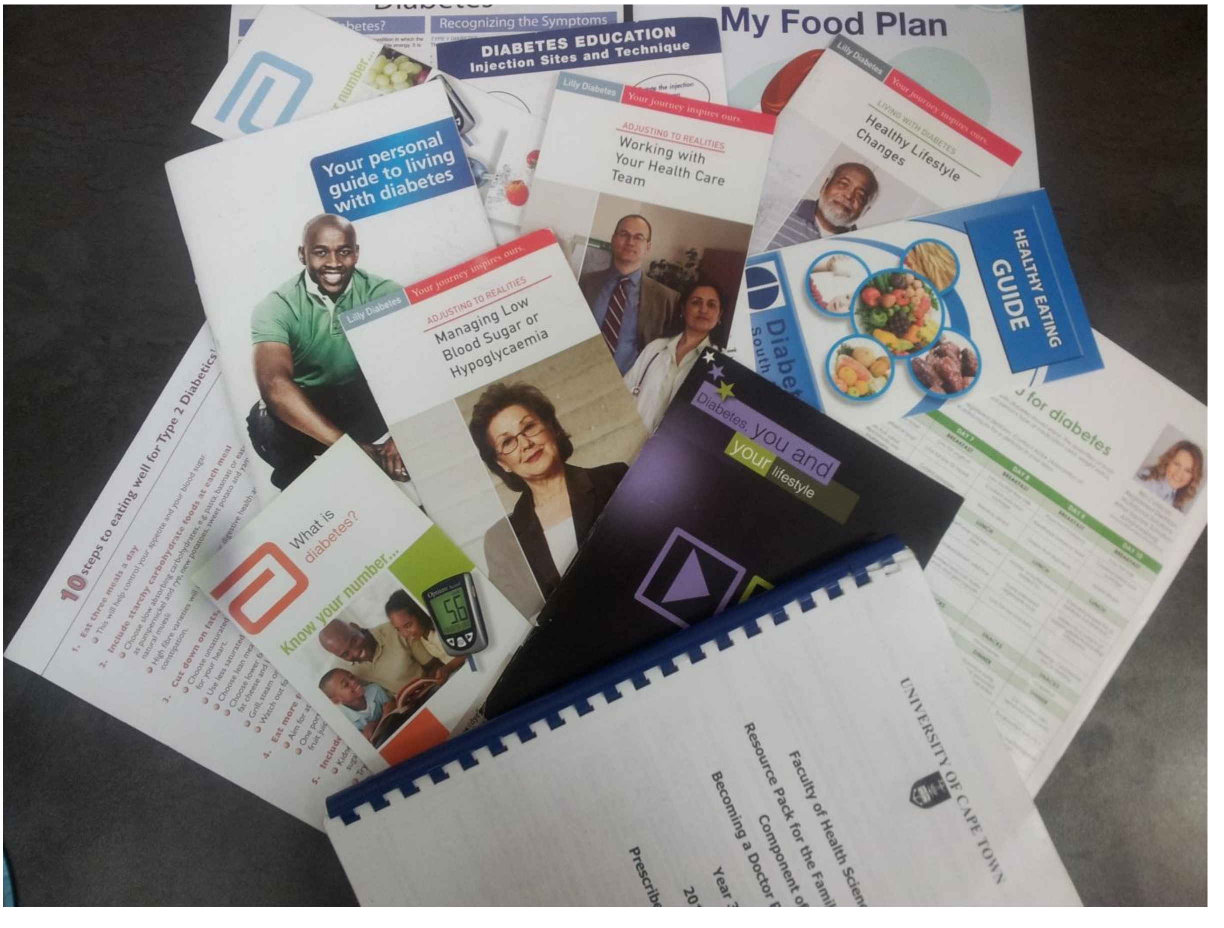


Figure 13: Books, flyers, and other resources that were issued from the second interview

Table 1: Second prototype questions

Patient Information	
Patient details: **Name :** **Age :** **Gender :**	
Questions	Valid input
Do you experience increased thirst?	(y/n)
Do you experience frequent urination?	(y/n)
Do you experience unexplained weight loss?	(y/n)
Do you experience increased hunger?	(y/n)
Do you experience blurred vision?	(y/n)
Have you seen a doctor for your symptoms?	(y/n)
Have you been diagnosed with diabetes?	(y/n)
Are you taking any diabetic medication?	(y/n)
Do you monitor your blood sugar level?	(y/n)
Do you have an exercise plan?	(y/n)
Do you have a healthy eating plan?	(y/n)
How often do you eat high fibre food?	(y/n)
How often do you eat low fat food?	(y/n)
How often do you eat sugary and fatty food?	(y/n)
How often do you eat milky and dairy food?	(y/n)
How often do you eat fruits and vegetables?	(y/n)
How many meals do you eat per day?	(y/n)
Do you smoke?	(y/n)
Do you consume alcohol?	(y/n)
Do you monitor your blood sugar level?	(y/n)
Do you experience a change in your appetite?	(y/n)
Do you experience tingling on hands and feet?	(y/n)
Do you feel dizziness or loss of balance?	(y/n)
Do you have slow hearing wounds?	(y/n)
Do you experience unexplained feelings of weakness and exhaustion?	(y/n)

3.6. Summary

Diabetes is 24 hours a day, every day, but patients do not get to see their human experts every day. MAS can provide instant access to advice, to help users better manage their diabetes. The main problem with managing diabetes is to monitor the sugar levels and with the right information and support from the system one can have a healthy lifestyle. Monitoring of blood sugar levels periodically and making appropriate adjustments are the main challenges for people living with diabetes. Every person living with diabetes needs to keep track of their health in order to have a normal daily lifestyle. Thus the MAS system is a great benefit for people with diabetes.

The use of a shell can reduce the amount of maintenance required and increase reusability and flexibility of the application. However, the tools are often specialised and may not match the exact requirements of a given problem. So the expert system language requires less rigid control of the execution sequence. The inference engine is used to apply the knowledge to the data. But in procedural language there is a tight interleaving of data and knowledge and programmers must carefully describe the sequence of execution. In expert system the separation of knowledge and data allows a higher degree of parallelism and modularity.

This chapter looked at all the aspects involved in a knowledge engineering process. The knowledge collected from the human expert was simplified such that it will be understood by a novice user. This chapter did not talk about knowledge base system because this aspect has been discussed in the previous chapter. The last two chapters will be discussed further in the implementation and testing chapters.

4. Software Implementation

The step after system design is implementation. To effectively develop an expert system needs a well-organized methodology which provided an idea of how to implement the expert system. The implementation process did not take a lot of time because the knowledge to be put into the system was already available. Building an expert system requires a lot of knowledge about the domain. The most challenging part during the implementation of this system was learning the language.

Implementation of an expert system

The Medical Advisor System was written in JESS (Java Expert System Shell) version 7.1p2. The system runs on any Linux operating system machine. The most challenging part in the implementation of the expert system is learning how to use the expert system tool. Because the language is different, learning JESS was the hard part of the project. Few JESS examples were shown in the previous chapter. This chapter only highlights the main parts of the system. The best way to demonstrate the implementation of an expert system is through a piece of code. The example below is an indication of a fact, annotated as deffacts in JESS. A fact is a piece of information that can be stored in a database. For example, *(user start-program)* is a fact that is executed first.

Example 1:

```
(deffacts initial-phase
  (User start-program))
```

However, example 2 shows a rule that executes this fact in MAS source code. Table 2 represents the JESS rule for example 2, the information on the right is the output given by JESS after executing the system.

Table 3 contains a portion of MAS source code.

Example 2:

```
IF
  The user chooses to start the program
THEN
  Ask the user to select what they want to do, and
  Get the user's response
```

Table 2: MAS main menu rule and its output

(defrule main-menu (user start-program) => (printout t crlfcrlfcrlf "Welcome to a Medical Advisor System. " crlfcrlf "Main Menu:" crlf "1. Medical Advisor System" crlf "2. Diabetes Information" crlf "3. Exit the System" crlf "Enter your selection: ") (bind ?choice (read)) (while (and (neq ?choice 1)(neq ?choice 2)(neq ?choice 3)) (printout t "Invalid input, enter (1, 2 or 3): ") (bind ?choice (read)))	*(if (eq ?choice 1) then (assert (selection-is 1))) (if (eq ?choice 2) then (assert (selection-is 2))) (if (eq ?choice 3) then (assert (selection-is 3))))* *Welcome to a Medical Advisor System. 1. Medical Advisor System 2. Diabetes Information 3. Exit the System Enter your selection:*

Table 3: Piece of MAS source code

;;;== ;;; Medical Advisor System <MAS>. ;;; Written by KulaniMakhubele ;;; JESS Version 7.1p2 ;;; To execute, merely load, reset, and run. ;;;=== *(deffacts initial-phase (user start-program)) ; ***** ; RULES ; ***** ; RULE main-menu ; IF ; The user chooses to start the program ; THEN ; Ask the user to select what they want to do, and ; Get the user's response* *(defrule main-menu (user start-program) => (printout t crlfcrlfcrlf "Welcome to a Medical Advisor System. " crlfcrlf "Main Menu:" crlf "1. Medical Advisor System" crlf "2. Diabetes Information" crlf "3. Exit the System" crlf "Enter your selection: ") (bind ?choice (read)) (while (and (neq ?choice 1)(neq ?choice 2)(neq ?choice 3)) (printout t "Invalid input, enter (1, 2 or 3): ") (bind ?choice (read))) (if (eq ?choice 1) then (assert (selection-is 1))) (if (eq ?choice 2) then (assert (selection-is 2))) (deffacts initial-phase (user start-program))*	*(defrule main-menu (user start-program) => (printout t crlfcrlfcrlf "Welcome to a Medical Advisor System. " crlfcrlf "Main Menu:" crlf "1. Medical Advisor System" crlf "2. Diabetes Information" crlf "3. Exit the System" crlf "Enter your selection: ") (bind ?choice (read)) (while (and (neq ?choice 1)(neq ?choice 2)(neq ?choice 3)) (printout t "Invalid input, enter (1, 2 or 3): ") (bind ?choice (read))) (if (eq ?choice 1) then (assert (selection-is 1))) (if (eq ?choice 2) then (assert (selection-is 2))) (if (eq ?choice 3) then (assert (selection-is 3))))* *(defrule first-selection ?p <- (user start-program) ?c <- (selection-is 1) => (retract ?p ?c) (printout t crlfcrlf "This medical Advisor system is designed to give medical advice on diabetes."crlf "It advises the user on the following aspects: " crlf "1. Healthy eating plan" crlf "2. Healthy exercise program" crlf "3. Monitoring blood sugar levels" crlf "4. Maintaining a healthy weight" crlf "5. Education on diabetes" crlf "Please note this system is not a diabetes diagnosis tool." crlfcrlf) (tested-diabetes))*

5. Medical Advisor Final System

This chapter outlines the execution of the final medical expert system. The expert system discussed in this chapter is also used for software testing (in section 6). There were many prototypes that were implemented for this system and most of them are outlined in chapter 4. This chapter will include snapshots of the program in action. Different patients will have different advice and different fact base tables. The patients that will be used in this example will be called Patient A and B. This chapter consists of four sections. The first section displays an overview of the final system and all the rules. The second section outlines the way JESS is executed in a Linux system using the batch file. The next section represents the advice and the fact table for two different patients. The last section will discuss the other branch that this expert system has. This branch gives a variety of information to the user about diabetes.

5.1. Final system overview

Table 4 illustrates the rules from the expert system. Figure 14 and Figure 15 displays a flow diagram of the final expert system and all the rules and facts are represented in the diagram.

Table 4: Medical Advisor System Rules

JESS> (batch system.clp) Defining deffacts: initial-phase Defining defrule: main-menu +j+j Defining defrule: first-selection Defining defrule: second-selection =j+j+j Defining defrule: third-selection =j+j+j Defining deffunction: tested-diabetes Defining deffunction: diagnosed-with-diabetes Defining deffunction: diabetes-type Defining deffunction: diabetic-medication Defining deffunction: medication-type Defining deffunction: exercise-plan Defining deffunction: exercise-type Defining deffunction: exercise-times Defining deffunction: eating-plan Defining deffunction: check-food-types Defining deffunction: sugar-monitor Defining deffunction: monitor-times Defining deffunction: sugar-average Defining deffunction: high-sugar Defining deffunction: low-sugar Defining deffunction: normal-sugar Defining deffunction: check-smoking Defining deffunction: alcohol-consumption Defining deffunction: symptoms Defining deffunction: seen-doctor Defining defrule: system-start +j+j Defining defrule: patient-is-diabetic Defining defrule: patient-is-diabetic +j+j	Defining defrule: is-patient-diabetic Defining defrule: urination-sym +j+j Defining defrule: hunger-sym +j+j Defining defrule: weight-sym +j+j Defining defrule: fatigue-sym +j+j Defining defrule: vision-sym +j+j Defining defrule: seen-a-doctor +j+j Defining defrule: not-seen-a-doctor +j+j Defining defrule: alcoholic +j+j Defining defrule: eating-plan +j+j Defining defrule: high-fibre-food +j+j Defining defrule: low-fat-food =j+j Defining defrule: fatty-food +j+j Defining defrule: milky-food-type +j+j Defining defrule: fruit-and-veg-food +j+j Defining defrule: meals-per-day +j+j Defining defrule: planning +j+j Defining defrule: have-exercise-plan +j+j Defining defrule: have-no-exercise-plan +j+j Defining defrule: bad-normal =j+j+j Defining defrule: bad-good =j+j+j Defining defrule: normal-normal +j+j+j Defining defrule: normal-good =j+j+j Defining defrule: no-healthy-eating-plan +j+j Defining defrule: healthy-eating-plan +j+j Defining defrule: smoking +j+j Defining defrule: excercis +j+j Defining defrule: bad-exercise +j+j TRUE JESS

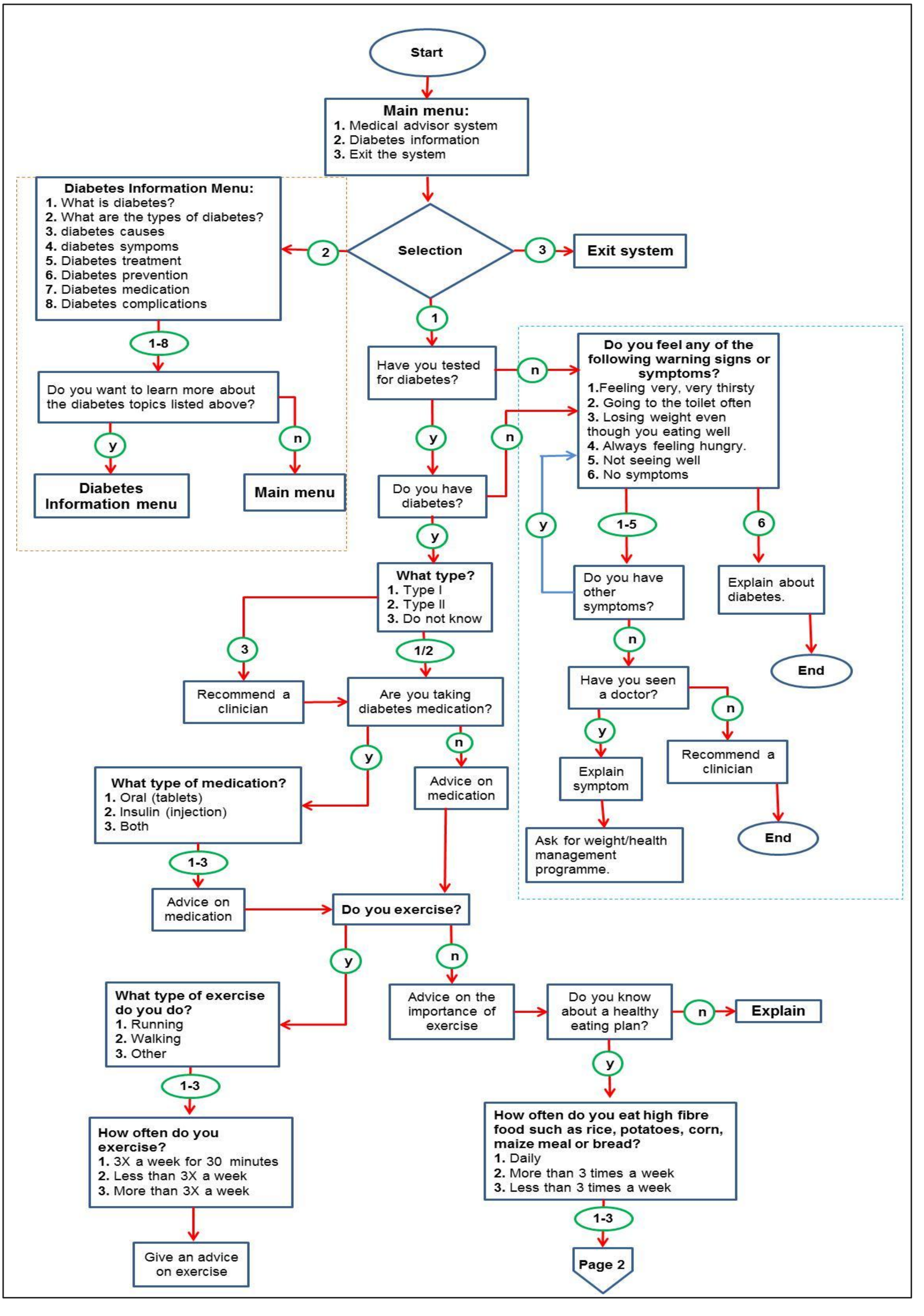


Figure 14-1: MAS final system flow chart

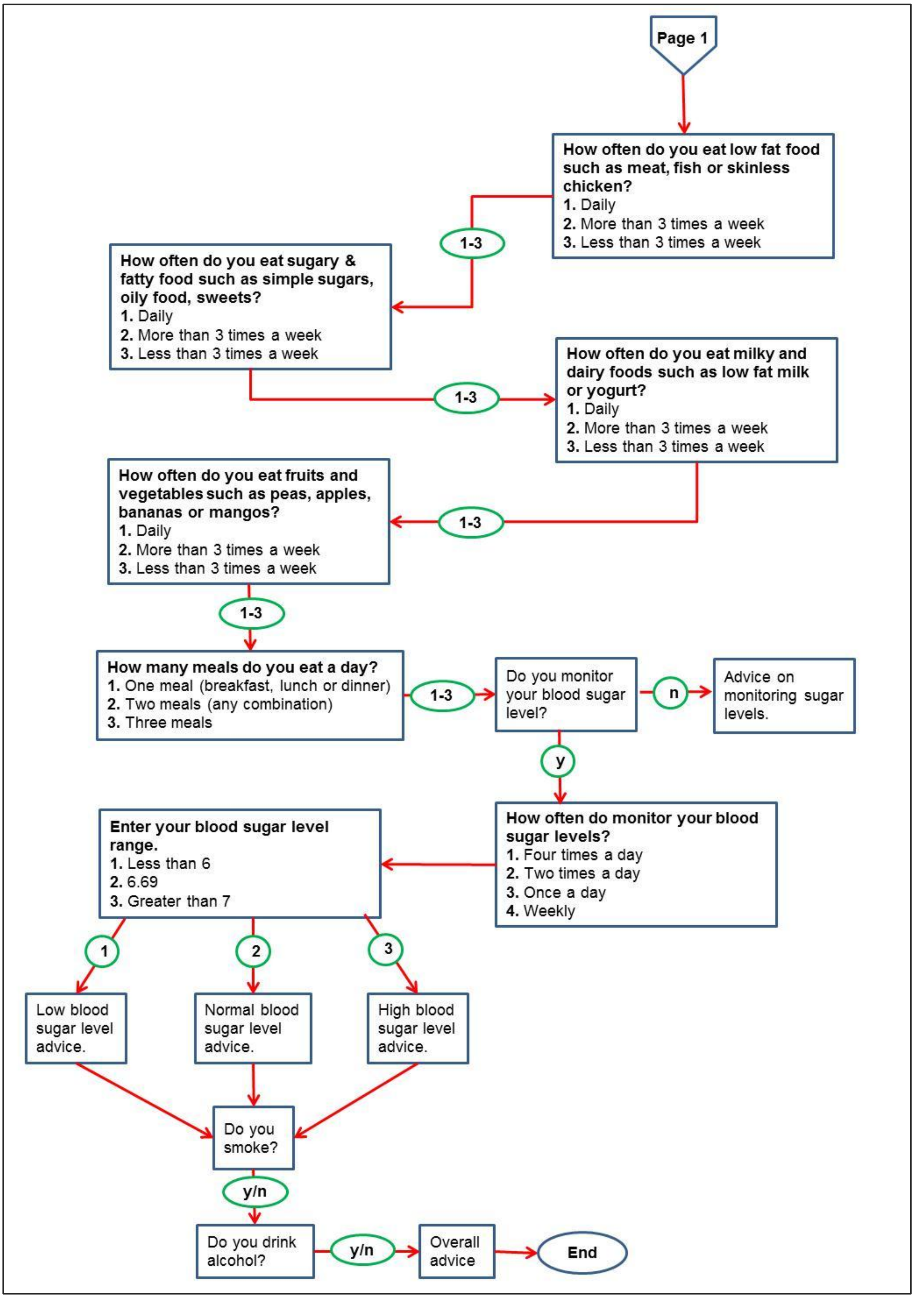


Figure 15-2: MAS final system flow chart

5.2. JESS execution in Linux

Figure **16** below shows how MAS works. The first command in
Figure **16** represents a path to where the JESS batch file is stored and the command *#:~/project/JESS/bin$* indicates a pathname. The statement '*shJESS'* is a command that is used to run JESS shell from a Linux operating system. The other information produced is the JESS welcome note. JESS version 7.1p2 was used to implement and to execute this system, and is valid for a year (365 days). After writing JESS code the file is saved as a .clp file, because JESS still shares many aspects with its parent, the CLIPS system, including the .clp file extension. The *(batch system.clp) is a JESS* command used to compile the program and the commands *(reset) (run)* are used to delete all the previous facts stored in the system and execute the system.

```
#:~/project/jess/bin$ sh jess

Jess, the Rule Engine for the Java Platform
Copyright (C) 2008 Sandia Corporation
Jess Version 7.1p2 11/5/2008

This copy of Jess will expire in 256 days(s)
Jess> (batch system.clp)
```

Figure 16: JESS executing system.clp file

```
Welcome to a Medical Advisor System.

Main Menu:
1. Medical Advisor System
2. Diabetes Information
3. Exit the System
Enter your selection:
```

Figure 17: Medical Advisor System main menu

Figure 17 displayed above shows MAS welcome menu. From the '*MAS welcome menu*', the user has an option to choose between getting medical advice and reading about diabetes. The user can also choose to exit the system. Option 1 asks the user to execute MAS and two examples will be presented below. Option 2 asks the user to read more about diabetes.

5.3. Option 1: The user chooses to use the system

Two examples will be used to illustrate how the system gives advice and what kind of advice the system gives patients. The first scenario is about a patient with diabetes and the second scenario is about a patient without diabetes. Figure 19 is an example of a fact base. A fact base is a simple fact storage that any expert system tool creates to store information that is entered by users. This information is stored after asking the patient the questions provided. It basically stores all the answers that a user inputs into the system. The output of the fact base table is dependent on how the system is designed.

```
(deffunction diabetic-medication ()
(printout t "Are you taking any diabetic medication? (y/ n)" crlf)
(bind ?answer (read))
(if (eq ?answer y) then (assert (patient takes-meds)))
(if(eq ?answer n ) then (assert (patient takes-no-meds)))

(defrule medication-type
        ?p <- (patient has-diabetes)
        ?p <- (patient takes-meds)
=>
(medication-type))
```

Figure 18: Example of how a fact base is created by an expert system tool

Figure 18 is extracted from MAS source code. It illustrates how rules are used to store information on the fact base. The resulting fact base table for the aforementioned example for a patient with diabetes and taking medication is:

f-0 *(MAIN:: initial-fact)*
f-1 *(MAIN:: patient has-diabetes)*
f-2 *(MAIN:: patient takes-meds)*

However, the fact base for a patient who has diabetes and not taking medication will be:

f-0 *(MAIN:: initial-fact)*
f-1 *(MAIN:: patient has-diabetes)*
f-2 *(MAIN:: patient takes-no-meds)*

Therefore the fact base only results from information that has been asserted to the working memory. Due to privacy and other issues involved, a scenario demonstrated in the section below will be used to execute the program instead of real data.

5.3.1. Scenario 1: For a person with diabetes

Patient A is a 20 year old woman, who has been living with diabetes for 2 years.
She does not know enough about diabetes management and has been taking insulin to treat her diabetes.

Figure 19 below is a fact base database; it has 18 facts that were executed during the consultation process. It indicates the information that MAS has on patient A. In addition, the system knows that patient A has type 1 diabetes and is a young female. This information is not shown in the fact base but the program does ask the patient about their age and gender. This is because diabetes also depends on factors such as age and gender. The system knows that patient A is taking insulin medication and she does not forget to take her medication. The system looks at the type of foods she is eating daily. It knows that she is taking three meals a day and that she drinks alcohol but does not smoke. The system also knows that she has a bad exercise plan and that she monitors her blood sugar level, and her range is low (<6 mmol/L). This information on the fact base will help the system to come up with good advice for patient A. Figure 20 shows the advice given to this patient. The medical advice given by the expert system varies with patients.

```
JESS>(facts)

f-0     (MAIN:: initial-fact)
f-1     (MAIN:: patient has-diabetes)
f-2     (MAIN:: patient-diabetic-type is-type-1)
f-3     (MAIN:: med-type insulin-medication)
f-4     (MAIN:: med-forget i-dont-forget)
f-5     (MAIN:: has-diet-plan)
f-6     (MAIN:: eat-high-fibre daily)
f-7     (MAIN:: eat-dairy-food daily)
f-8     (MAIN:: eat-low-fat-food daily )
f-9     (MAIN:: eat-fatty-food daily)
f-10    (MAIN:: eat-fruit-and-veg daily           )
f-11    (MAIN:: eat-meals three-meals)
f-12    (MAIN:: exercise-time bad)
f-13    (MAIN:: exercise-duration good)
f-14    (MAIN:: sugar-monitor is-good             )
f-15    (MAIN:: has-low-blood yes)
f-16    (MAIN:: drinks alcoholic)
f-17    (MAIN:: smoke non-smoker)

For a total of 18 facts in module MAIN
```

Figure 19: Fact base sample for patient A.

Figure 20 shown below is the medical advice that was given to patient A after using the program. Different colour represents different advice. Each advice comes from a different rule but all advices are given at the end of the system. The medical advice given by the system is absolutely not the same for different patients. If there is any condition that the system cannot help a patient with, the system will refer the patient to a clinic or hospital.

The recommendation happens a lot for people without diabetes because the system does not want to make assumptions. The advice is kept at minimum and only information that is valuable to the patients is added to the system.

Given advice:

Now that you have diabetes, you must make sure that you manage your diabetes properly.

Please remember to take your medication as your doctor or nurse tells you. You must take your tablets the same time every day, with meals. Do not stop taking your medication unless your doctor tells you to. Always make sure that you have enough medication to last you until your next clinic visit. Remember that you must not use the same place for injection every time because you medication can stop working. You can change sides a place daily.

It is good that you have a healthy eating plan. Remember to eat your meals in small portions, 3 meals a day with snacks in between you meals is advisable.
It is important that you have variety of this type of food every day. Drink a lot of clean water as well.

High fibre food: Eat 2 – 3 portions of this type per meal.
Here are some recommendations you can eat:
Breakfast: oats, bread, corn,
Lunch/Diner: sweet potatoes, potatoes, samp, maize meal, rice.

Milky and diary: Eat 2 - 3 portions of milky or protein food each day such as fat free milk, eggs or low fat plain.

Low fat: Eat 2 – 3 portions of low fat food each day such as low fat milk, low fat yoghurt,

Fatty food: You must be very careful while eating fatty foods. Too much fat can make you put on weight. Remember cut off all fat meat and remove chicken skin before you prepare your meal. Avoid using oil while preparing your meal.

Fruit and vegetables: Eat different types of fruit and vegetables every day. Eat 3 - 5 portions each day to provide you with vitamins, minerals and fibre to help you to balance your overall diet. For fruits, a portion is: 1 banana, 1 mango, 1 apple…
For vegetables a portion is: 1/2 cup of spinach, 1/2 cup of peas and 1/2 cup of mixed veg …

Exercise plan: Bad exercise is bad for your diabetes. You must try to exercise more often. You can choose any exercise that you will enjoy as suggested during the consultation. Exercise daily for 30 – 45 minutes at least.

Low blood sugar level is very bad. It can result in what they call "hypoglycaemia" which means low blood sugar level, this condition is very serious. It is recommended that you get a proper test from the clinic.

Drinking alcohol is not restricted for people with diabetes, but you must drink at most 1 unit per day.

Thank you for using the Medical Advisor System
Goodbye!

Figure 20: An example of an advice given to patient A

5.3.2. Scenario 2: For a person without diabetes

Patient B is a 40 year old woman, who is always thirsty and has frequent urination. Her family has a history of diabetes.

Figure 21 below is a fact base; it has 6 facts that were executed during the consultation process. The system knows the following information about patient B. The system knows that patient B is an older female, who has a history of diabetes in her family. She has never tested for diabetes before but she has two diabetic symptoms and she has not seen a doctor for her symptoms. Because the tool is not a diagnosis tool, the system cannot assume that patient B has diabetes. The good advice that the system can give the patient is to recommend that patient B visits a clinic. The advice given to patient B is shown in the Figure 22.

```
JESS>(facts)

f-0   (MAIN::initial-fact)
f-1   (MAIN::patient has-never-tested)
f-2   (MAIN::symptoms is-thirst)
f-3   (MAIN::symptoms is-urination)
f-4   (MAIN::patient has-diabetic-family)

For a total of 5 facts in module MAIN
```

Figure 21: Fact base sample for patient B

Figure 22 below is the medical advice that was given to patient B after using the program. This is short advice because the fact base has less information about the patient. Besides, the system cannot diagnose the patient. However, the system does explain to the patient what the possible causes of the symptoms are.

Given advice:

It is highly recommended that you go see a doctor or nurse.

The fact that you are always feeling thirsty may be because your bodyhas excess glucose stored and water is being drawn from your body tissues. This includes dehydration from frequent urination, thus causing you to drink more water or other fluids to satisfy your thirst.

Urination becomes more frequent when there is excess glucose in the body. For people with diabetes the excess glucose in the blood builds up, therefore the kidneys are forced to work overtime to filter and absorb the excess sugar. When the kidney cannot keep up, this normally results in frequent urination.

People with a family member who is living with diabetes are always at risk. This is one of the causes of diabetes.

Thank you for using the Medical Advisor System
Goodbye!

Figure 22: An example of an advice given to patient B

5.4. Option 2: the user chooses to read more about diabetes

The main purpose of this option is to help patients and any medical assistant to learn more about diabetes. Figure 23 below is the diabetes information menu, which basically asks the user what information they want to get from the system. The user can only select one option and read about it. The system will then ask the user after reading if they want to navigate back to the main menu in Figure 17 or if they want to read more about other information provided from the information menu. Figure 24 also shows the information that the user receives after selecting option 1 from the menu below.

Diabetes Information Menu:
1. *What is diabetes?*
2. *What are the types of diabetes?*
3. *Diabetes causes*
4. *Diabetes symptoms*
5. *Diabetes treatment*
6. *Diabetes prevention*
7. *Diabetes Medication*
8. *Diabetes complications*

Enter selection:

Figure 23: Showing Diabetes Information Menu

Enter selection: 1
Diabetes mellitus is a clinical syndrome characterized by high blood sugar levels, due to absolute deficiency of insulin. The lack of insulin affects the metabolism of the body. This causes an increase in the blood sugar levels because there is not enough insulin to reduce the percentage of glucose to its normal level. Insulin is a hormone produced by the beta cells in the pancreas, which helps to control the amount of glucose absorbed into the blood cells. In people with diabetes the beta cells either produce too little or no insulin.

Figure 24: Showing Information for “What is diabetes?” option

5.5. Summary

The purpose of the chapter was to give a brief outline of how the system works and what kinds of diabetes advice the expert system will provide the patients with. The knowledge in this system was approved by a human expert in the field of diabetes. The advice that the system gives was recommend by the human expert as well. There are many types of advice that the system has for different patients. However, only 2 patients were discussed here to demonstrate how the system works. The advice is given from time to time as the interaction proceeds but added together at the end, so that the system can give as much information as possible for different patients.

6. Software Testing

Software testing is an investigation conducted to check the quality, performance and reliability of a system. Software testing is important, but it is a time consuming and frustrating process. Software testing involves a couple of strategies such as planning and management strategies. A strategy for software testing must accommodate tests that are required to verify that a piece of code has been implemented according to its specifications. The software testing strategy must also be able to validate major system functions against user requirements [50]. Software testing is often referred to as verification and validation (V&V) [51]. Verification is the process of ensuring that an expert system is consistent with no conflicts or errors as well as to ensure that it is functioning according to its specifications. Verification tests are intended to check the consistency of the knowledge base [52]. In addition, verification tests are intended to check if the system is built correctly. Validation is a method of ensuring that the expert system is doing the job it was intended to do. There are many techniques used for expert system testing; Turing test is one of the techniques that were used to test expert systems [53]. The definition of V&V encompasses many software quality assurance activities. This chapter outlines some aspects used for expert system testing and the verification and validation of the MAS system.

6.1. Formal Technical reviews

A formal technical review (FTR) is a software quality control activity performed by software engineer to uncover errors in a function. FTR verifies that software meets its specifications and ensures that the software has been represented according to predefined standard [54]. Other common techniques for verification and validation are inspection and empirical testing. Inspection is a technique where a human expert evaluates the knowledge base while empirical testing involves running the system with test cases and analysing the results [55]. The FTR is a class of reviews that includes inspection.

6.2. Testing for the MAS system

The testing of the MAS expert system discusses the testing of the knowledge base and outlines the testing of the complete expert system. In addition, each section has verification and validation tests and results.

6.2.1. Knowledge base testing

The purpose of knowledge base testing is to check if the system contains correct and consistent knowledge. This is designed to check the correctness of the knowledge put into the system and the usefulness of the knowledge in the knowledge base.

Verification

The purpose of the knowledge base verification process is to ensure that the knowledge base has no errors or faults that might have been introduced during the design and implementation process. After the implementation of the system, the knowledge contained in the system was examined and corrected by a human expert. Due to time constraints, the knowledge base verification was done only twice. Since verification is a process, it is better to test the knowledge base many times to eliminate more internal errors. Every rule in the knowledge base was considered, to check if it provides correct advice and if it does not ask information that will never be used by the system. The knowledge base was verified by domain experts.

Validation

The purpose of knowledge base validation is to ensure that all the divisions and subdivisions that need to be considered in the system are actually considered, as well as ensuring that all the right questions are asked at the right time. The validation test mostly validates the advice provided by the system and checks if correct information was included in the system. The validation test looked at the correctness of the knowledge base designed and if the system did exactly what it is supposed to do. Unfortunately, the validation of the knowledge base with a human expert was only done once. It was outlined during user testing that the knowledge in the system was accurate and will be very helpful to people living with diabetes. Three domain experts were used in the testing of the system. Two of these experts had experience with advising people living with diabetes. The kind of testing that was performed in this system was quantitative testing, and aimed at having all the branches of the knowledge base tested. But due to time constraints, a flow chart was used for other parts of the knowledge base. The flow chart used was a full paper prototype of the knowledge base system.

All possible test case combinations were generated in the flow chart to fully test the system. The main reason of having a flow chart is to minimise the testing duration.

6.2.2. Expert system testing

The purpose of system testing is to ensure that the system is running properly. The main focus of this test is to check the performance and accuracy of the system.

Verification

The purpose of the expert system verification is similar to that of the knowledge base except that the main test is the knowledge representation. The knowledge base was verified by a human expert and the system was verified by domain experts. These two terms are used differently throughout the testing chapter in order to differentiate them. A human expert in this sense is an individual who was involved in the designing of the expert system. A domain expert is an individual who has medical expertise and was never involved in the design.

6.3. Evaluation of the system

Evaluation is a technique used to demonstrate the performance of the system and its acceptance by the end user. The purpose of the evaluation process is to get the end user’s views on the significance or usefulness of the system. The system was evaluated looking at the following criteria: utility, accuracy, consistency, advice description for both the knowledge base and the system tests. After the user read the information sheet in Appendix A, the navigation of the system was much easier during the testing process. In this case the users are domain expert, so the advice provision was familiar and valuable comments were given. The evaluation questionnaires of the system were presented to the users and the section below discusses the results and comments provided for each question asked.

Few comments were made based on the entire system and the knowledge base; the most concerns were about adding more questions to give the system more information about the patient. Here are some of the concerns that were raised during the interview. It was suggested that it is a good idea to also ask the patient if they are controlling their blood sugar levels.

The other comment was on the eating plan – the system ask about the types of food the patient eat and advises them on that – it was suggested that is a good idea to include the following question: “How many portions of food do you eat a day? ” – Do you eat 4 slices of bread, 2 -3 full spoons of rice or porridge? If they eat three meals a day and eat in small portions, do they include snacks in between their meals? It is also advisable to give advice on complications that a person with diabetes can have. Such a heart attack, high blood pressure and others that were mentioned in section 2.2.

6.3.1. Results and Discussion

A summary of the results for the knowledge-based expert system is given. Table 5 represents the questions that users used to evaluate the system. Table 6 shows the evaluation results.

Table 5: Evaluation Questions

Questions number	Questions
Question 1	A person with no computer skills can be able to use this system?
Question 2	The clinics or hospitals can use this system to learn more about the field expertise?
Question 3	This system can free physicians from boring routine tasks?
Question 4	This system can be very useful to physicians or nurses in rural areas?
Question 5	This system does look at all branches needed to be considered by a physician while giving advice?
Question 6	Even though I am a medical student I can rely on this system for advice instead of going to a specialised doctor?
Question 7	I would recommend this system to my diabetic patient if necessary?
Question 8	The advice provided by the system is correct and useful?
Question 9	The advice provided by the system can be understood by people with poor literacy?

Table 6: Evaluation Results

Average Responses	Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Not applicable
Agree	1	1	2	1	-	-	-
Agree	2	-	4	-	-	-	-
Agree	3	-	3	1	-	-	-
Agree	4	1	3	-	-	-	-
Agree	5	1	3	-	-	-	-
Agree	6	1	3	-	-	-	-
Strongly Agree	7	3	1	-	-	-	-
Agree	8	2	2	-	-	-	-
Agree	9	-	3	1	-	-	-

It is found in Table 6 that most users agree that a person with no computer skills can use this system. Therefore this system can be deployed in rural areas and everyone will be able to use it. The users commented that it is a good idea to have yes or no answer rather than asking a user to enter full answers or sentences. This aspect is important because most people in rural areas have low computer skills, fully textual answers will not work for them. For question 2, it was found that all users agree that the system can help medical assistants to learn more about diabetes. Thus the system could be utilized to decrease the rate of diabetes in rural areas through awareness and diabetes management programmes.

For question 3, it was found that most users agree that the system can be very helpful and could reduce some of the workload for medical assistants especially during peak times. The system tries to give brief explanations to avoid delaying clinicians and patients. This will decrease the long queues in clinics because other patients can still use the system without assistance. For question 4, it was found that most users agree that the system will be very useful in rural areas. This is because there is a shortage of expertise and medical facilities in rural areas. Therefore the system gives suggestion to the users' information that is of relevance to them.

For question 5, it was similarly found that the users agree that the system consider all branches that need to be considered while dealing with people who are living with diabetes as well as people who are mostly at risk. The system does consider all the information about managing diabetes. It looked at healthy eating plan, exercise plan, medication and monitoring blood sugar levels. It was suggested that it will be a good idea to include information about how to prepare meals and how to use insulin injections. For question 6, it was found that more users agree that they can also rely on the system for advice. Therefore, the system does provide good advice.

For question 7, it was found that most users strongly agree that they would recommend the system to their diabetic patients. Hence, the system does provide concise information that a patient can read and understand. In addition, the system explains everything to give the patient an idea of question and its relevance. For question 8, it was found that most users agree that the system provide correct and helpful advice. This means that the system does what it was meant to do. Similarly for question 9, it was found that most users agree that the advice given by the system can be understood by patients with poor literacy.

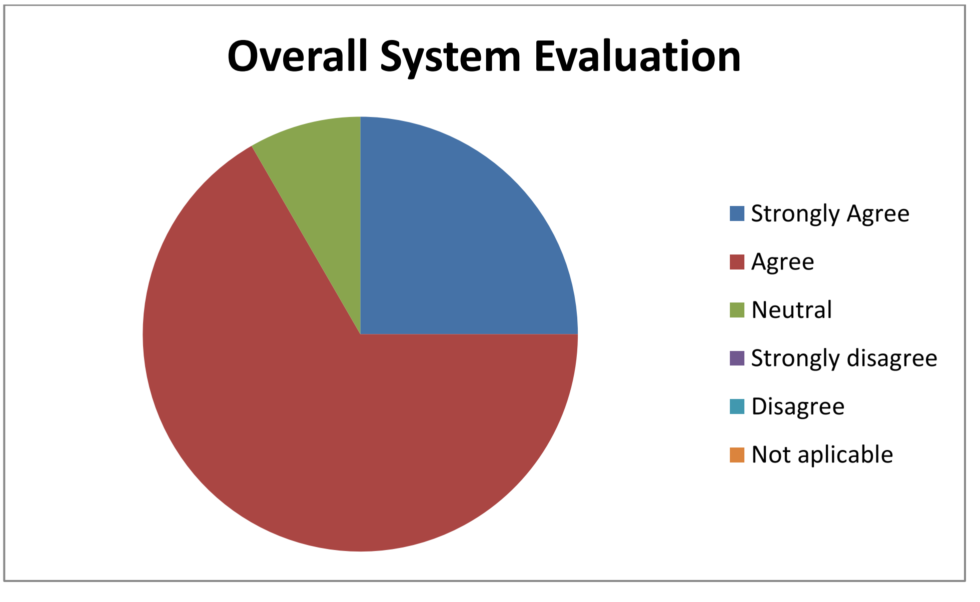


Figure 25: The overall system evaluation

Figure 25 shows an average evaluation of the system. It was found that most people (about 65%) generally have positive feedback about the system, especially about the knowledge that system contains. This graph shows that the entire system is working well in terms of quality, performance and reliability.

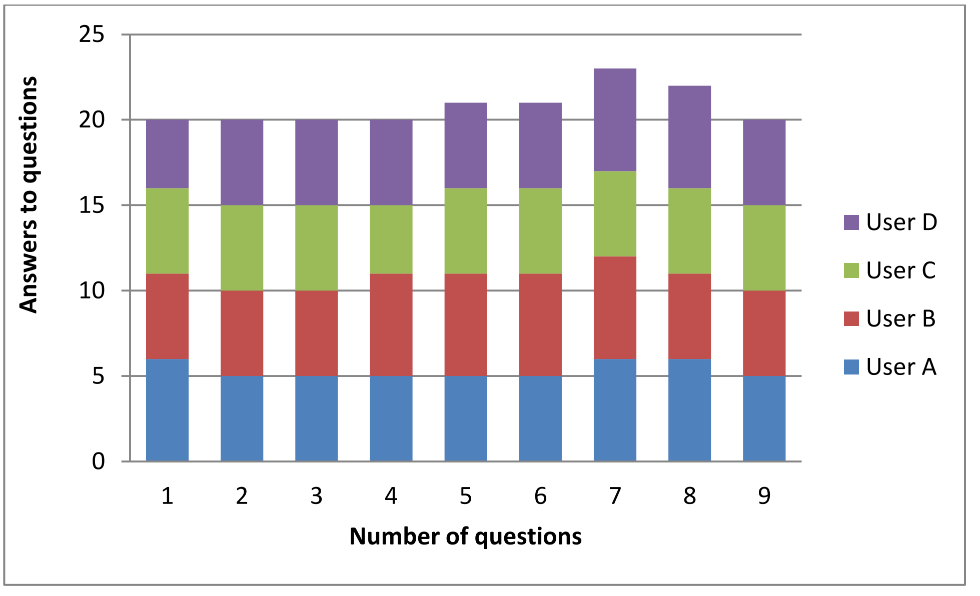


Figure 26: Number of questions answered

Figure 26 depicted below outlines the questions that were rated high by users. It was found that the system will be very useful in helping medical assistants in rural areas to get the work done faster. However, Figure 26 below represents the average percentage at which the questions were answered. It was found that the questions were equally answered. These results are very good and positive. Most users were very overwhelmed with the system.

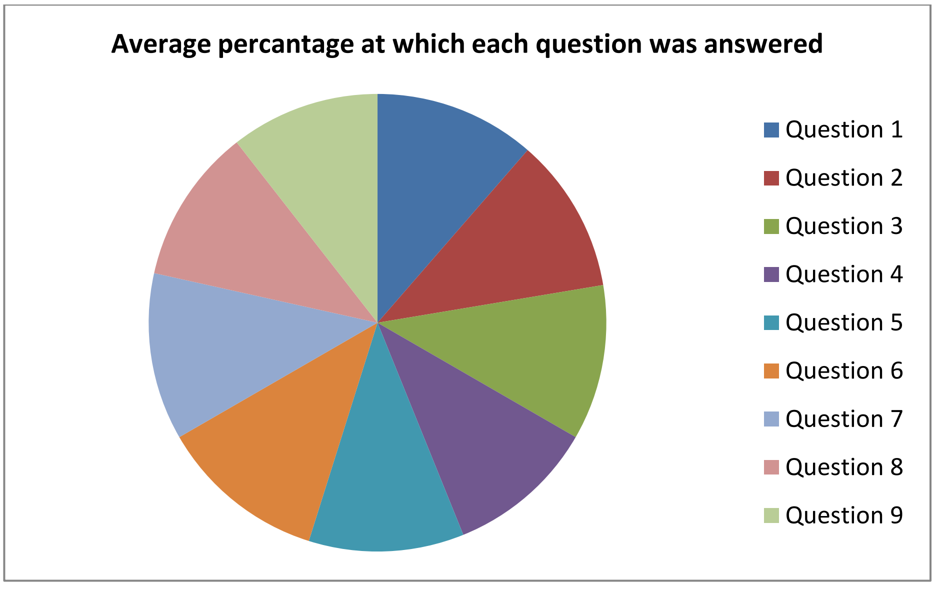


Figure 27: Average percentage answers per each question

6.4. System improvement

All the comments that were made on the system were positive. The system will be updated to add the suggested information. The more knowledge the system have the better the advice. The knowledge base will add the following information:

- To ask the user if they have a way that they are using to control their diabetes
- To ask about the quantity and quality of the food they eat
- To ask about family history if a person has diabetes
- To ask more questions about diabetes long term and short term complications. In order give an advice to a patient on how to prevent them
- To ask the patient with diabetes about their symptoms in order to see if they have to consult a doctor
- Explain first to the user the meaning of “accepted blood sugar level” before asking them to enter their sugar level so that they will know if they are doing something wrong.

Based on the results discussed above, the system was a success and many users mentioned that it is a good system. It will be very useful and helpful to people with diabetes in rural areas.

6.5. Summary

The MAS system has demonstrated good performance as validated by domain experts. The results illustrated have shown the potential value and usefulness of the system. It was confirmed that this system can be useful to people living with diabetes in rural areas. Because diabetes is a common condition, it was commented that the system can be a very good start for people living with diabetes. It was argued that the system provides correct and useful advice. The key aspect that all the users seemed to notice was the system explains everything. This is a good thing because doctors do not have time to explain symptoms and risk factors to patients all the time. This system can help ignorant patients by giving them more knowledge on the disease affecting their bodies. Comments were added that the system is more user friendly because it just requires one to answer with a ‘yes’ or ‘no’ where applicable.

The users commented that the system was very accurate and on point. The most aspect that many of them commented on is the ability of the system to give feedback as the consultation progresses. The system was developed with a human expert, so the advice and diagnosis it provides is realistic and reliable. The system also looks at all aspects that need to be considered such as food, exercise, medication and how to monitor blood sugar levels. It was suggested that it will also be useful to give advice on how to prepare a meal especially for someone living with diabetes, for example, not eating red meat and to remove fat while preparing a meal.

7. Future work

Many users were pleased with the system especially the knowledge it contains. During software testing many suggestions were made about enhancing the system. The following is a list of suggested ideas:

The Web-Based Medical Advisor System

The system can be useful to many clinics not just rural areas. The implementation of a web-based medical advisor expert system using JESS could certainly be the future research for this prototype. The web-based system can use the same rules and facts used in this system to give advice. However, the architecture of the system will be different because other components are added into the system. These components include the server, JSP technologies and XML translators. The web-based system can be accessible to everyone who needs advice.

Medical Advisor System with explanation facility

An explanation facility is the part of an expert system that explains its reasoning to the user and also allows the user to ask questions about provided information. In addition, a user can ask the system how it has reached it decision. The integration of the explanation facility to the medical advisor system can very useful. However, as stated in the report this kind of system will not mean much to an average patient. This kind of system can be very useful to a medical student or medical assistants because they can learn how a particular piece of advice was reached and improve their own skills.

8. Conclusion

The main purpose for this research work was to develop a prototype of a knowledge-based system to help people who are living with diabetes in South Africa, especially in rural areas. The system was designed and implemented as outlined in the methodology. The knowledge implemented in this system was obtained from a human expert and other sources such as books and the Internet. The developed system was a success because many users confirmed that the system will be very useful in rural areas and that the system contains a good knowledge base. The system was able to give advice to “patients” with different conditions. People can learn with the system whether they have diabetes or not. Patients can get advice without consulting a doctor. The system considers a lot of diabetes management plans such as exercise, diet and medication. For an example, with exercise the system looks at how the patients is currently exercising then give advice based on what they are doing wrong and the system also suggests other ways to exercise. All advises that the system give depends on what the patient is currently doing, that is if the patient has a plan. The system makes it a point to suggest as many possible activities that the users in rural areas can afford. The system is very helpful to people with diabetes as that was the main key of the project. However, the advice given to a person without diabetes is minimised. This is due to the fact that this system is not a diagnosis tool and it does not do any diagnosis. The best thing it does in this situation is to recommend a patient to the clinic.

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10. Appendices

10.1. Appendix A: Information Sheet

Department of Computer Scince

University of Cape Town

This is the information sheet for a Computer Science honours project. The system to be evaluated is the Medical Advisor System. More details about the system will be provided in the evaluation system. Please note that this is a quantitative evaluation it will require you to evaluate in all the branches of the system.

Study title

A knowledge based system for medical advice provision.

Invitation paragraph

You are being invited to take part in a research study for a knowledge-based expert system. Before you take part in this research it is important to understand why this study is being done. Please take time to read the following information carefully.

What is the purpose of the study?

The aim of this research is to develop a prototype expert system for the provision of medical advice on diabetes. An expert system is a computer program which captures the knowledge of a human expert and uses this knowledge to solve a real-world problem in real time. In this study we are capturing the knowledge of a human expert in the medical science field. The system consists of two parts the knowledge-based system and the mobile application. However this test is for a knowledge based system. This knowledge-based system is called a Medical Advisor System. It is developed to give advice to people living with diabetes, advise on how to manage their lifestyle changes.

Why have I been invited to participate?

The evaluation part of the system requires people with medical expertise, because the system is developed for medical assistants in rural areas to receive the knowledge of a medical expert. We chose you to evaluate our system because you have expertise in the medical field. This system will be evaluated by fifth and final year medical student only due to the aforementioned reasons.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What will happen to me if I take part?

The aim of this evaluation is to collect more knowledge and to test the system; the data collected will be used for those reasons. Each participant will be asked to test the entire system. The approximated time for testing is 15-20 minutes per candidate. Each candidate will be paid a sum of thirty rand.

What are the possible benefits of taking part?

The main benefit for you is to gain knowledge and you will be paid for doing taking part in this study. You should outline any direct benefits for the individual and any other beneficial outcomes of the study, including furthering our understanding of the topic.

Will what I say in this study be kept confidential?

All the information provided in this study will be kept strictly confidential. Please also note that confidentiality, privacy and anonymity will be ensured in the collection, storage and publication of research study. The data generated by this study will be retained in accordance with the University's policy on Academic Integrity. The data generated in the course of the research will be kept securely in paper and electronic form for a period of ten years after the completion of a research project. The data will be stored in the computer science project website together with this work. However you names will not be included in this case.

What will happen to the results of the research study?

The results of this research will only be used for this work that is if you state that this should be the case. Otherwise you can also agree that it can be used by other researches to evaluate related systems. This study will never ask you to provide your name or other personal information. You are allowed to state that the information you provide in this study cannot be used. Please note that the information provided will be published unless if stated otherwise by the participant.

Who is organising and funding the research?

This work is organised and funded by the department of computer science at the University of Cape Town.

Who has reviewed the study?

This study has been approved by the University Research Ethics Committee, University of Cape Town.

Contact for Further Information

You can contact me at kulani.makhubele@gmail.com or you can contact my supervisor at audrey.mbogho@uct.ac.za . If you have any comments or concerns about the way in which the study has been conducted, you can contact the University of Cape Town Research Ethics Committee on http://www.health.uct.ac.za/research/humanethics/adminteam/

Thank you for taking you time to read this information sheet.

Date

20 October 2012

10.2. Appendix A: Consent Form

Department of Computer Science
University of Cape Town

Consent Form

Title of Project : *A knowledge based system for medical Advice provision*

Degree : *Computer Science Honours*

Please initial box

I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason. ☐

I agree to take part in the above study. ☐

I agree that my data gathered in this study may be stored (after it has been anonymised) in a specialist data centre and may be used for future research. ☐

________________	__________	______________
Name of Participant	Date	Signature
________________	__________	______________
Name of Researcher	Date	Signature

10.3. Appendix A: Medical Advisor System Questionnaire

Medical Advisor System Questionnaire

A medical Advisor System is an expert system that is designed to help people with diabetes to manage their lifestyle. The system does not do diagnosis therefore it will not give advice to people without diabetes. However, the system gives advice on the following matters: Healthy diet plan, an exercise plan, drinking and monitoring the blood sugar level. The system also helps educate the people with diabetes as doctors do not really have time to explain all the symptoms, risk factors and complications about diabetes. Please note that the answer provided in this questionnaire will only be used for this work.

General Computer Experience

Please circle your choice:

- I have used computer and have more programming experience (expert)
- I have used the hospital computer-based systems to enter data but I have no computer experience (user)
- I have no experience with computers (novice)

System questions

1. A person with no computer skills can be able to use this system?
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree
    f. Not applicable

2. The clinics or hospital can use this system to learn more about the field expertise?
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree
    f. Not applicable

3. This system can free physicians from boring and repetitive tasks?
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree
    f. Not applicable

4. This system can be very to physicians or nurses in rural areas?
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
   f. Not applicable

5. This system does look at all the branches needed to be considered by a physician while giving advice?
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
   f. Not applicable

6. Even though I am a medical student I can rely on this system for advice instead of doing to a specialised doctor?
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
   f. Not applicable

7. I would recommend this system to my diabetic patient if necessary?
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
   f. Not applicable

8. The advice provided by the system is correct and useful?
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
   f. Not applicable

9. The advice provided by the system is can be understood by people with poor literacy?
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree
    f. Not applicable

Any comments you wish to add: