Honours Project Report

Diabetes Risk Assessment Web Based Expert System

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

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This thesis is dedicated to
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Joyce & Enezael Mmari.

My siblings:
Diane, Walter, Irene, Amanda.
& Isaac.

A truly inspirational family.
I have really been blessed beyond measure.
I love you all

♡

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Kevin... we done did it!

-Namaste-

Abstract

Diabetes is a chronic disease , with over 350 million people currently estimated to have the disease worldwide [5]. Statistics state that about 78% [1] remain undiagnosed in Africa alone. This can be attributed to: a lack of awareness, low literacy levels as well as the high cost and limited availability of medical professionals. Diabetes is not a well known disease amongst the communities of the undeveloped world. Thus, the consequences and complications brought by the disease are unknown to a large portion of Diabetes sufferers. As a result of this, there are a lot of people experiencing the symptoms that come with the onset of Diabetes, yet still living a lifestyle that only worsens the condition. In Africa alone there are about 344,000 [2] deaths a year due to Diabetes and Diabetes related complications.

The proposed solution to this problem is a prototype web-based Expert System that offers an interactive risk assessment facility as well as advice on Diabetes management and treatment. The user interacts with the system by answering a series of questions dynamically posed by the expert system as well as giving input of their currently experienced symptoms. The Expert System provides comprehensive feedback throughout the assessment to keep the user involved, followed by a percentage diagnosis of the user's chances of having developed Diabetes.

The application was designed with the aim to have informative and useful content. Along with a highly intuitive and usable graphical user interface. This is to ensure that users of all literacy levels are able to utilize the system with relative ease. This system has been thoroughly tested with doctors, medical students and normal users with the aim to assess and improve the usability, feasibility and usefulness of the system. Positive feedback was received during the testing and evaluation process, as well as many useful suggestions for further improvements to be made on the system. All of the users involved in the testing process stated that this system has the potential to have a positive impact on the developing world.

Keywords: Expert Systems, JESS.

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Chapter 1

Introduction

1.1 Problem Outline

Diabetes is a life threatening chronic disease with over 350 million people affected worldwide [5], with the International Diabetes Foundation (IDF) stating that this figure will grow to about 500+ million in 2030. In Africa about 78% [1] of the estimated Diabetic population remain undiagnosed, this can be attributed to a lack of awareness, a lack of medical education and limited access to medical professionals. Diabetes has two distinct types, Type 1 diabetes and Type 2 diabetes, with Gestational Diabetes occurring in about 2%-10% of all pregnant woman. An individual can unknowingly develop and live with Diabetes for a very long time. This is because there are a variety of symptoms that come with the disease (i.e thirst, fatigue, excessive urination etc) that are not life- threatening. These symptoms may not raise any immediate concerns in an unsuspecting victim. Furthermore, with Type 2 Diabetes regarded as asymptomatic[1] in a large number of cases, the only way to check your diabetic status is to do a blood glucose test at the clinic with a qualified medial professional.

Because of the lack of education in certain undeveloped communities, there are certain misconceptions about diseases like Diabetes. It is common to find that the symptoms of the disease like sugar in the urine, are known to be experienced; but the exact cause and reason is unknown, leading to wrong diagnosis if any at all. Because of this there are a large number of people living with the disease that are not doing anything about it, as they are neither aware of their status nor the grave complications that could develop overtime (if not treated immediately).

With a population of about 52 million the ratio of patients per doctor in South Africa is about 1300 on average, according to the World Health Organization. Because of this low ratio, it means that in certain more remote and less-urbanized areas patients will need to travel a significant distance simply to get access to a medical facility. When these medical facilities are eventually reached, there are high service costs incurred for simple check-ups and one-on-one doctor consultations.

[1] Type 2 Diabetes is often asymptomatic in its early stages and can remain undiagnosed for many years

Taking all the above factors into consideration we can presume that there is a significant number of undiagnosed diabetics living in South Africa, having little to no knowledge of their current medical condition. Lack of knowledge of their status and/or of the disease prevents them from prolonging their life by taking the correct treatment and applying the appropriate lifestyle changes.

1.2 Project Overview

1.2.1 Proposed System

The aim of this project was to build a prototype rule based expert system that offers a Diabetes risk assessment facility to users regardless of their apparent literacy level. The intended objective is to have the system offer professional information and advice on Diabetes, very similar to what would be expected during consultation with a qualified endocrinologist [2]. The system shall contain information with regards to the symptoms, causes and complications of Diabetes as well as management advice (for diabetics) to ensure healthy living with the disease or prevention (for non-diabetics) from developing the disease in the future. The proposed system has been designed to have an intuitive, easy-to-use and interactive interface so that users of all literacy levels can utilize the system effectively, with minimal external assistance. This system shall be hosted on a server as a web- application to ensure ease of access to users, who will only need to have a computer/mobile device and an internet connection to access the application at any time of the day and from any location with sufficient internet access.

1.2.2 Objectives

The main objectives of this project are:

Provide users with a realistic Diabetes risk assessment.

We aim to provide users with a facility to asses their chances of developing/having already developed Diabetes. This shall be done through engaging the users in a brief question-answer session with the system. The user shall be asked to input certain information into the system, which shall be used to provide relevant feedback as well as a percentage measurement of their chances of having Diabetes.

Provide comprehensive on-line information on Diabetes.

A lack of education seems to be a contributing factor to the large number of undiagnosed people living with the disease[5]. This application will aim to provide detailed information on Diabetes to users; detailing how it is brought about, what the risk factors are and how to manage it effectively. We aim to provide comprehensive yet concise explanations on the core concepts of the disease.

[2]Endicronology is a complex study of the various hormones and their actions and the disorders of the body. Diabetes is one of the most common conditions seen by an endicronologist

Figure 1.1: Diabetes is currently a worldwide problem

Provide an easy to use interface for users of all literacy levels.

The target market for this application is users of lower literacy levels. We aim to develop a very intuitive user interface, that is usable and very easy to understand with basic computing knowledge.

1.2.3 Relevance

This developed system is only a prototype. It has been built with the aim to research and further explore the possibility of developing and deploying similar fully functional expert systems that can be used for risk assessments, advice and even diagnosis (where possible) of Diabetes and other diseases. Ideally, systems like this could reduce the dependency on medical professionals in communities. Without trying to completely substitute the need for medical professionals these systems could be used in a supplementary manner in those areas where professionals are scarce and/or very costly. Also expert systems such as this could be used as an educational tool for the general public, to self-assess their health and find out more about the management and prevention of certain diseases.

1.2.4 Evaluation Criteria

The success of this project is based on the perceived usefulness of the application as a whole. Three specific user groups are involved in the testing and evaluation process:

1. Doctor(s).
2. Medical students.
3. Normal users.

The doctors and medical students assist with validating the information used and the advice given by the system. While the normal users, who are of all ages and all backgrounds; are used to assess the usability, understanding and intuitiveness of the system. Due to the lengthy ethical clearance process involved and the limited time duration of this honours project we could not test the system on less literate individuals in rural communities (this being the target market).

1.2.5 Thesis Outline

This remainder of this report is partitioned into four parts. In the background section we take a deeper look at Diabetes and Expert Systems, the two base components of this project. This is followed by the system development section which contains the methodologies used and provides a more detailed explanation of the overall design of the system. The testing and evaluation section explains how the testing process was approached and carried out, with a detailed analysis and discussion of the results. Finally the last section concludes the project and also expands on some ideas that look at the possible directions for future work.

Chapter 2

Diabetes Mellitus

Diabetes Mellitus, more commonly known as Diabetes, describes a group of metabolic non-communicable[1] diseases in which a person has a high count of blood glucose (sugar) in their body. This occurs mainly because of the following two reasons:

1. The body does not produce enough insulin.
2. The cells in the body do not react appropriately to the insulin.

Insulin is a hormone produced and secreted naturally within the pancreas that is used to control the amount of glucose in the blood. The normal production of insulin allows muscles and other tissue within the body to take glucose from the blood and convert it into energy. Administering insulin to a diabetic does not cure the Diabetes. However, it does make living with the disease a lot more manageable in the long term. Before the discovery of insulin in the early in the 20th century, Diabetes was a greatly feared disease with diabetics quickly succumbing to their death without even the slightest hope of prolonged survival.

There are two distinct types of Diabetes, along with Gestational Diabetes. Pre-diabetes is the term given to the condition in people with high glucose levels that are not high enough to indicate Diabetes.

2.1 Type 1 Diabetes

Often referred to as insulin-dependent or juvenile diabetes. Type 1 Diabetes describes the condition where the body does not produce insulin. It is mostly seen in children and young adults [4]. Type1 Diabetes accounts for about 5% to 10% of all diagnosed cases of Diabetes.

[1] A non- communicable disease is non-infectious and cannot be transmitted between people.

2.2 Type 2 Diabetes

In Type 2 Diabetes, either the body does not produce enough insulin for proper everyday functioning or the cells do not react properly to the insulin. Type2 Diabetes is the most common variety of diabetes in the world as it accounts for about 90%-95% of all types of diabetes [17].

2.3 Gestational Diabetes

This occurs in about 2%-10% of all pregnancies making it one of the most common health problems associated with pregnancy. When a woman is pregnant the hormonal changes occurring within the body can make the cells less responsive to insulin. In most cases it disappears when the pregnancy is over, with a small percentage of woman eventually being diagnosed with Type 2 Diabetes after the pregnancy period. It shares many similarities to Type 2 Diabetes [5].

2.4 Symptoms

People with Diabetes are unable to deal with sugar appropriately because of either insulin failure or insulin resistance. This leads to a high blood glucose level in the body. If not managed well this condition has many internal and external effects on the body that manifest through a variety of symptoms.

The symptoms of Diabetes are as follows:

Abdominal Pain
This is a caused by Gastroparesis[2]. This results in inadequate grinding of food by the stomach into the intestine, causing pain during the digestive process.

Nausea
Nausea is another symptom of Gastroparesis.

Blurred Vision
This can be caused by the tissues being pulled from the eye lenses, affecting the eyes ability to focus. Another reason is due to the high blood glucose levels leading to light sensitivity. If not treated in time this can result in prolonged vision problems and eventually blindness.

Excessive Urination
When there is excess sugar in the blood, the body will try and remove it through urination. Taking water from the blood in order to dilute the glucose.This fills up the bladder, leading to frequent urination throughout the day.

[2]Gastroparesis is a disease of the muscles of the stomach and the nerves in the stomach that causes the muscles to stop working, affecting the digestive process, resulting in pain, nausea and vomiting during digestion.

Dry Mouth

This is a result of the dehydration within the body.

Extreme Hunger

Due to the insulin failure within the body, the body's cells are deprived of energy. This will lead the body to try and find more energy in the form of food. Leading to abnormal hunger.

Extreme Thirst

Because of the dehydration induced by the excess urination, this prompts the desire for increased water consumption.

Fatigue

The body's cells are deprived of energy, resulting in lethargy and fatigue.

Irritability

A result of the lack of energy within the body.

Gum infection

The high glucose levels in the saliva promote the growth of bacteria, resulting in gum disease and mouth infections.

Numbness

The excess sugar in the blood causes damage to the nerves and the blood vessels that supply the nerves. This leads to numbness and a loss of sensation in different parts of the body.

Erectile Dysfunction

This is a result of the nerve damage and loss of sensation in males. Casing males to have issues with keeping erect during sexual intercourse.

Yeast Infection

The excess sugar in the body affects its ability to recover from infections. Woman find it hard to recover from bladder and vaginal infections. This also causes itchiness around the vaginal area.

Slow Healing Wounds

The excess sugar in the body affects the body's ability to recover and heal.

Weight-loss

Due to the insulin failure within the body, the body's cells are deprived of energy. The body will seek alternative sources of energy leading it to break down muscle tissue and fat, resulting in weight- loss.

2.5 Risk Factors

There are a few factors that will increase the chances of someone having Diabetes. Certain risk factors like lifestyle and weight can be regarded as controllable. Whereas other risk factors like age, family history and ethnicity are uncontrollable and unchangeable.

Family history

Research shows that there is a 3 fold increase in the chances of developing Diabetes for someone who has a diabetic as a first degree relative.This is because Diabetes has a strong genetic basis.

Obesity

Obesity is officially classified as having a BMI[3] of greater than 30Kg/m^2.[18] states that obesity is becoming a worldwide concern because it is strongly associated with several major health risk factors. Studies show that obesity and weight gain are associated with an increased risk of Diabetes.

Lifestyle

Other risk factors are predominantly based on a persons ongoing lifestyle habits. The consumption of alcohol, smoking cigarettes, exercising and daily eating habits; all have a massive effect on an individuals health and susceptibility to Diabetes.

2.6 Treatment and management

Diabetes is a chronic condition that unfortunately cannot be cured at all, only treated and maintained. The aim with the treatment is too keep the blood glucose levels within the body as near to normal as possible. Because of the different lifestyles lead by Diabetics, a treatment strategy should be agreed on an individual basis, as there is no generic solution that will apply perfectly for all Diabetics.

2.6.1 Type 1 Diabetes

Type 1 Diabetes is difficult to control thus the treatment is a daily task.The strict regimen includes a carefully calculated diet, planned physical activity and multiple insulin injections. As well as a home blood glucose testing facility to check the levels throughout the day.

2.6.2 Type 2 Diabetes

Type 2 Diabetes treatment typically includes diet control, frequent exercise, a home blood glucose testing facility and in certain cases oral medication and insulin. The majority of Type 2 Diabetics do not require insulin injections.

[3]Body Mass Index is your weight divided by height^2. Measured in Kg/m^2

2.6.3 Gestational Diabetes

As Gestational Diabetes is brought about by hormonal effects of the pregnancy. The patient needs to ensure they exercise appropriately and maintain a healthy diet throughout the pregnancy to avoid developing type 2 Diabetes in the long run. Keeping the blood sugar within range throughout the pregnancy is very important. If this is a persistent problem then insulin shots may be required.

Chapter 3

Expert Systems

Expert systems are a sub-field of Artificial Intelligence (A.I) that aim to model the behaviour of a human expert [4]. They are computer software systems that use Artificial Intelligence to solve a problem or provide advice for specific situations known as problem domains. Expert systems are used in specific areas that would usually require the elicitation of professional human expertise (i.e medicine). These systems are based on the transfer of expert human knowledge from one or more experts in a field into a computer system through the process of knowledge engineering. This allows the system to be utilized in an expert-like advisory capacity [19].

Expert systems are used in a variety of different situations and their applications can range from different fields such as agriculture, finance, education, medicine, military services, process control, space technology and engineering [16]. These specialized services can make an unprecedented impact in developing countries where there is a clear need for an improvement in facilities like healthcare, training and education.

3.1 Importance of Expert Systems

Expert systems have experienced vast growth in certain fields over the past few years [17]. This is because of the advantage they have over traditional programming approaches. Traditional computer programs have a set algorithm that is followed, applying pre-set reasoning strategies to solve problems, these are called procedural programs. The majority of problems will fall under this category. However, there are certain problems that cannot be solved using conventional methods as they require a higher level of thinking and reasoning. For some complicated problems no straight forward solution technique is known at all, as these problems do not have a predefined structure that can be easily manipulated by traditional means. A few problems that fall under this category are diagnosis, scheduling and fault monitoring. For these problems Artificial Intelligence is required.

Artificial Intelligence is used to tackle such problems that require a thought process analogous to human reasoning. The core goals of A.I research are reasoning, knowledge, planning, learning

and communication. Expert systems focus more on the reasoning aspect of A.I, with the aim of encapsulating human knowledge and reasoning in a computer.

3.2 Architecture of an Expert System

An expert system is made up of four distinct parts, namely the knowledge base, the inference engine, the working memory and the user interface. These parts shall be described in detail below.

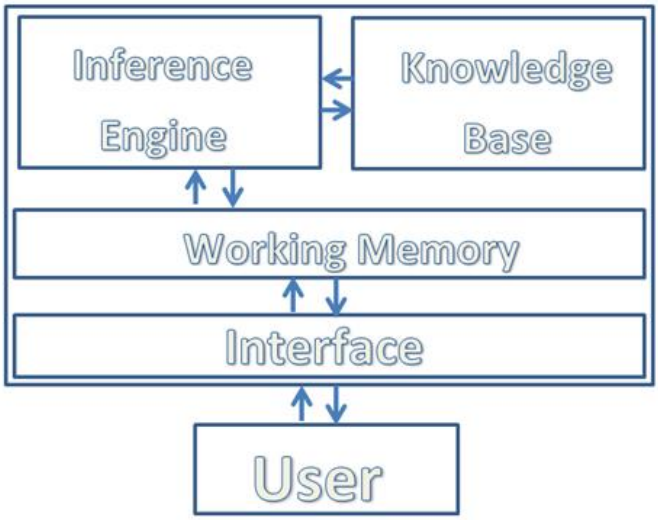

Figure 3.1: Components of an Expert System

3.2.1 Knowledge Base

The Knowledge base stores all the facts and rules about a particular problem domain. The initial facts form the background information built into the system. The rules include both the production rules that apply to the domain of the expert system and the heuristics or rules-of-thumb that are provided by the domain expert in order to make the system find solutions more efficiently.

3.2.2 Working Memory

The working memory is where all the facts and information gathered during a particular user session with the system are stored. These facts all together form case specific knowledge. In certain learning expert systems, such facts could eventually form part of the core knowledge base of the Expert System; as opposed to being discarded after the session is complete.

3.2.3 Inference Engine

The inference engine drives the expert system as it forms the central part of a rule engine. It uses the provided knowledge in the working memory and the rules provided in the rule base to infer new knowledge and eventually come to a conclusion. This is analogous to the problem solving abilities of humans. The inference engine is itself comprised of three components: a pattern matcher, an agenda and an execution engine. The pattern matcher compares the rules to the contents of the working memory, to decide which ones should be *activated*. This forms a list of activated rules, known as the *conflict set*. The conflict set is then ordered by a process known as *conflict resolution*, to form the agenda. The agenda is a list of rules which shall be executed by the execution engine.

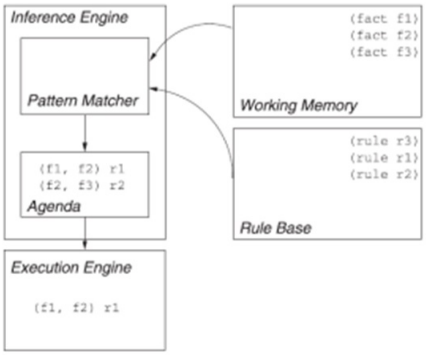

Figure 3.2: The components of an inference engine

Pattern Matcher

The inference engine needs to decide on what rules to fire and when to fire them. This is the job of the pattern matcher, to decide on which rules to fire based on the contents of the working memory. The difficulty of this process depends on the number of rules in the rule base and the number of facts in the working memory. Pattern matching is often the most expensive part of the entire process [8].

Agenda

Once the inference engine has decided on which rules should be fired, it still needs to decide on which rules to fire first. This list of rules is stored on the agenda. The agenda in turn uses a conflict strategy to decide on the ordering of the rules to be fired. This is based on priority (salience). For rules that have the same priority, either a depth[1] (LIFO) strategy or a breadth[2](FIFO) strategy is applied.

[1]When using the depth strategy more recently activated rules are fired before less recently activated rules

[2]When using the breadth strategy the rules are fired in the same order that they are activated

Execution Engine

Once the ordering of the rules is complete, the execution engine fires the rules.

Forward and backward chaining

There are two inference mechanism that expert systems use: forward chaining and backward chaining. Forward chaining starts with the initial facts and then works forwards towards the conclusion, drawing new sub-conclusions along the way. This is known as a data driven approach. Backward chaining starts at the conclusion (the hypothesis) and then works backwards to the supporting facts. Along the way, new sub-goals are set for validation. This is known as a goal driven approach. The system described in this report implemented forward chaining.

3.2.4 User Interface

The user interface is the primary means of communication and interaction between the system and the user. The system receives input from user through the interface. In our case the Expert System can ask questions and make statements through the interface. User interfaces can either be text based or graphical.

3.3 Rule based expert System

In rule based expert systems, expert human knowledge is used to solve real-world problems that would require human intelligence [6]. This expert human knowledge is represented on the system as a set of production rules. A rule is a conditional statement that prompts a certain action or set of actions once a precondition has been satisfied. A basic production rule takes the form of:

If A $\Rightarrow$ B.
If A is true then do B

Where **A** can be a list of preconditions (the premise) and **B** can be a list of statements (the conclusion). **A** could contain a combination of facts entered by the users, and/or facts already stored in the system. The aim of a rule based system is to tend towards some sort of conclusion, being the solution to the initial problem. This can be in the form of a diagnosis or a recommendation.

3.3.1 Rule engine

In a rule based system the programmer only writes the rules. There is a runtime system known as the rule engine that decides which rules apply at any given time, executing them when appropriate. Because of this, rule based versions of complex programs can be much more simpler, shorter and easier to understand than the procedural equivalent. The functionality of the rule engine is the crux of rule based expert systems.

Chapter 4

Expert System Building tools

Expert Systems are usually written in dedicated programming languages. This is because general purpose programming languages like C and Java are not catered for rule processing and symbolic processing[17].

The main difference between Expert system languages and the more conventional procedural languages is the level of abstraction provided by the former. Expert system languages separate the data from the methods of manipulating the data [17]. Whereas with procedural languages there is much tighter interleaving between the two. In rule based languages there is a separation between the facts (data abstraction) and the rules (knowledge abstraction). Because of this, there is less need for a firm control of the execution sequence. This provides a lot more freedom and flexibility when it comes to making changes to the logic of the program. In procedural programming languages there is a much tighter merge between the data and the knowledge that makes use of and manipulates the data. Programmers have to describe the sequence of execution in detail as this is necessary for the program to work as intended. The level of abstraction provided by expert system provides a higher degree of modularity. Because of this degree of similarity, these languages are used to model and replicate human thought and reasoning.

4.1 Declarative Programming

Much of the programming done is procedural by nature [8], whereas rule based programming is declarative. With procedural programs, the programmer explicitly tells the software what to do. This is analogous to an algorithm; to a step by step approach to solving a problem. Procedural programming suits problems where the input is well defined and there is a clear path known before hand on how to solve the problem. A declarative program on the other hand, describes what should be done, but does not enforce a strict definition on how it should be done. For this reason, declarative programs need to be executed by a runtime system (rule engine) that understands how to fill in the blanks and use the provided information to solve the problem, in a declarative manner[8].

Declarative programming is seen as a more natural approach to tackle the following problems:

- Diagnosis
- Prediction
- Classification
- Pattern recognition
- Situation Awareness

Most problems that cannot always be solved by a clearly defined algorithmic solution would fall under the above category. For the web- based expert system described in this paper, the JESS programming language was used. Other languages that are used to develop Expert Systems are LISP (LISt Processing) and CLISP (C Language Integrated Production System)

4.2 Motivation for using JESS

JESS stands for Java Expert System Shell; often regarded as a superset of CLIPS - an open source rule engine written in C. JESS is a rule engine and scripting language written in Java, developed in the late 1990s [8]. Jess is fully compatible with Java-based software systems as it can make reference to all of Java's classes and libraries. There is a readily available JESS library that can be embedded in Java software. Jess can also be extended either through Java code or within JESS itself, allowing for easy customizations for specific applications. These features make JESS the ideal candidate to be used in the development of a Java-based web application. There was the possibility of developing a rule engine from the bottom up, but this would have taken a lot more time and effort. A JESS licence (valid for 365 days) was obtained for educational purposes free of charge (commercial licences are also available).

JESS includes a full-featured development environment based on the Eclipse platform, called the JESSDE[1]. JESS can be executed in three ways:

- Through the command line interface.
- Using a Graphical User Interface.
- As an embedded Expert System, by utilizing the JESS library.

[1] JESS Development Environment

4.3 Working with JESS

The JESS language has a simple syntax that is quite different from Java's (in JESS every command is enclosed in brackets). It is an interpreted program, which makes is extremely fast. The JESS language has a few built in data types: INTEGER, FLOAT, STRING and LONG. There are several simple control structures, along with the possibility of defining your own functions using the *deffunction* construct. Because JESS can reference the entire Java API, you are able to call any Java method and make use of any Java data structure (array, linked list, hashmap etc.) provided you import the correct package beforehand.

4.4 JESS programming features

The following elements form the basic features used when programming in JESS: templates,variables, functions, rules and facts.

4.4.1 Facts

In JESS, facts (working memory elements) are stored in the working memory, also known as the fact base. There are two types of facts: ordered facts and unordered facts. The following functions are associated with JESS facts:

- (assert) - Adds facts to the working memory.
- (clear) - Clears the current JESS program.
- (deffacts) - Defines the initial contents of the working memory.
- (facts) - Displays the current contents of the working memory.
- (reset) - Initializes the working memory.
- (retract) - Removes a fact from the working memory.

The (watch) command allows you to view the operations in the console as they happen while a JESS program is running. This is great for debugging purposes.

Unordered facts

Unordered facts are a key component of a rule-based engine. The following example illustrates an unordered fact.

(Question (section Initial) (text "Hello, what is your name?) (type "NAME") (answerType "INPUT")

The reason it is called an **unordered** fact is because the following representation is regarded as

exactly the same

(Question (answerType "INPUT") (text "Hello, what is your name?)(type "NAME")(section Initial))

With an unordered fact, the elements (i.e 'section', 'text', 'type', 'answerType') within the fact, known as **slots** can be specified in any order. As an analogy, unordered facts could be thought of as a row of a table in a relational database. Ordered facts on the other hand lack structure and are usually used for short, simple bits of information. The following is an example of an ordered fact

(Name "Benjamin" "Mmari")

The *deffacts* construct as earlier is used to define the initial contents of the working memory. When the program is reset, only the *deffacts* remain.

4.4.2 Templates

In JESS before you make use of an unordered fact it needs to be defined. This is almost like the schema for a table in a database. the *deftemplate* construct is used to define the slots in an unordered fact. This is the deftemplate for the unordered fact describes earlier.:

(deftemplate Question
(slot section)
(slot type)
(slot text)
(slot answerType
(default "YES-NO"))
(slot ask
(default yes))
(slot order)
(slot options
(default ""))
)

The name of the *deftemplate* (in this case, Question) is used as the head of the fact, you can define as many slots as you want in a *deftemplate*. Each slot has a value type, the default is string. And each slot value can have a default value, this will be asserted if no other value is explicitly given.

4.4.3 Rules

A rule has two main parts to it. The first part is the list of facts that much be satisfied. The second part is the list of actions that must take place if that rule is fired. The *defrule* construct is used to

create rules. The following is a trivial example:

(defrule greet
(Name ?name ?surname)
=>
(printout t ("Hello" ?name ", how are you today"))
)

The above rules will only fire if there exists an unordered fact *(Name)* that has two values, *?name* and *? surname*. *?name* and *?surname* are variables, this is how variables are referenced in JESS, with a "*?*" as a prefix to the variable name. *printout* prints the given text to the output router, the default output router is defined as *t*, which prints out to the console. Additional routers can be added to the JESS program, this can be used to reroute output to a web page or to a file.

Salience

When developing a rule based expert system, some rules may have a higher priority than others. To ensure that the rule engine recognizes this, salience values are used. The higher the salience value, the higher the priority. Salience values are whole numbers that can either be positive or negative. With all rules the default salience value is 0.

An example of using a salience value to establish priority:

(defrule greet
(declare (salience 10))
(Name ?name ?surname)
=>
(printout t ("Hello" ?name ", how are you today"))
)

4.4.4 Functions

Users can add their own functions using the *deffunction* construct. A value can be returned by choice using the *return* statement, else nothing will be returned. The following is an example of a simple user defined function:

(deffunction multiplyby5(?number)
(bind ?newNumber (?number 5))*
(return ?newNumber)
)

The above example takes in a number as input and returns the number multiplied by 5. The *bind* construct is used to bind a given value to a variable. Local variables do not have to be defined

before they are used in JESS. Also the argument types need not be specified either.

4.5 Embedding JESS in Java

A typical JESS file (fileName.clp) will contain all of these above mentioned features. When embedding JESS in Java, you crate the Rete object and then load a file that has all the JESS logic in it as follows.

Rete jessObject = new Rete();
jessObject.batch(fileName.clp);

The Rete class is the central class in the JESS library, this is the rule engine itself. Each jess.Rete object has its own working memory, agenda, rules, etc.[8]. The API[2] has all the possible methods (assertFact(), reset(), run() etc.). that can be used to manipulate the Rete object in a Java file.

[2]http://herzberg.ca.sandia.gov/docs/70/api/jess/Rete.html

Chapter 5

Previous Work

5.1 MYCIN

MYCIN, one of the very early Expert Systems; was developed at Stanford University in the mid 1970s. It was designed to assist doctors in the diagnosis and treatment of meningitis and bacteremia infections [13]. At the time, positive in-laboratory identification of these fatal and infectious blood diseases could take up to two full days. The severity of such a situation meant that in most cases treatment needed to be administered in the absence of complete laboratory results, as there was a need to act quickly in order to identify the exact cause and prescribe the right medication in a timely manner.

The role of MYCIN was to effectively take the place of a consulting physician that specialized in bacteremia and meningitis. To achieve this, MYCIN would engage in an extensive dialogue with the doctor, asking numerous questions consecutively until eventually providing a diagnosis and a drug therapy recommendation. MYCIN was written in the LISP programming language. A limitation of MYCIN is that it would take a long time to reach a conclusion (around 30 minutes), this was seen as too lengthy. The interface was a simple terminal, which offers poor usability especially for non-programmers. Also, because of the time period (1970s) in which it was developed; the computers used to run MYCIN had limited storage space and processing power.

5.2 ESDD

ESDD, an Expert System for Diabetes Diagnosis is a rule based medical expert system for the diagnosis of Diabetes [17]. Developed in 2010 as part of masters research at Christ University, Bangalore. This system has three main menu options: Diagnosis, Complications and Diabetes trainer. This system is not able to identify the type of diabetes. The focus was on identifying the general level of Diabetes risk in the patient. ESDD makes use of a command line text-based user interface to interact with the user, communicating in simple English.

ESDD has a trainer option that can be used to provide diabetes awareness amongst the public.

Also during the diagnosis process the system is able to give comprehensive explanations about the causes of the disease. A lengthy task that a physician may not be able to accomplish because of time constraints. ESDD is a stand alone application written in the CLIPS programming language.

5.3 An Expert System for Endocrine Diagnosis and Treatment using JESS

This expert system was developed to diagnose and treat patients with Pancreas, Thyroid and Parathyroid gland diseases. Additionally it also gives first aid in emergency cases caused by Diabetes [15]. This system is not meant to replace the physician but rather to assist them in doing their work. This system had a Graphical User Interface , that took the user through two phases, providing feedback on each phase. The system could be used in English or in Arabic, giving user the option of the language that they prefer. ESDD is a stand alone program developed in JESS and JAVA.

5.4 MAS

MAS, Medical Advisor System is a prototype rule based Expert System developed as part of an honours project at the University of Cape town 2012 [3]. This system offers patients with advise on Diabetes management. The system engages with the user in a series of questions regarding their health and diet. On completion, the system provides advice relating tot he user's input. MAS is a standalone program developed in JESS and uses a standard command line interface to interact with the user.

5.5 Artificial Intelligence Approach to Diabetes Diagnosis

The concept of designing and building an intelligent system in Diabetes diagnostic is introduced in this paper. The Expert System discussed in the paper can diagnose the following types of Diabetes:

- Type 1 Diabetes
- Type 2 Diabetes
- Other defined types of Diabetes
- Gestational Diabetes

The date used can be from the following sources: the patient, the patients records, the physician, specialist, biochemical lab and specialist tests. The system gathers data through the following tests: subjective, objective, laboratory and additional tests.

Subjective tests

This is historical data as well as demographic data such as name, surname and age. Occupation, lifestyle and family history. If the patient or any one in his family has Diabetes then what is the duration of Diabetes.

Objective tests

This is more measurable data like height and body mass measurements, gender, blood pressure, thyroid test, heart test, pulse etc.

Laboratory tests

Blood glucose level , urine tests, cholesterol level, neurological tests etc.

Additional test

Findus test.

After all the information pertaining to the patient is collected, the Expert System draws conclusions on their background. A decision tree is used. The system can categorize the patients Diabetes to one of the four classes and the recommendation made is a proper diet and the appropriate pharmacological treatment. This Expert System makes extensive use of laboratory tests which would require a dedicated physician/nurse to assist with. This would only be useful inside a hospital with someone who is trained to use the system.

5.6 Summary

From the related work it is clear that this is a fairly active area of research, as this problem has already been tackled on a number of occasions. The system discussed in this paper aims to build on the previous work were possible as well as focus on the usability and the usefulness of the Expert System itself. The systems outlined in previous work have not focused much on the usability or the ease of use of the system. With most of them making use of a command line interface which are not intuitive or attractive for the novice computer user. Furthermore, all of the above mentioned systems are standalone programs, this greatly limits the accessibility of the system. By developing a web-based system, there is a greater accessibility to the system, making it much more relevant in the modern internet age.

Chapter 5

Methodology

5.1 Approach

The developed system has two main aspects to it:

1. Expert System.
2. User Interface.

Because of the limited time available for development, we opted for a more delivery focused approach with our web-application as opposed to the traditional waterfall methodology. An approach known as RAD; Rapid Application Development was taken. This was done mainly to ensure that we had functional presentable software at all times and also to minimize the possibility of scope creep towards the end of the development period; which often plagues software engineering projects.

With both the user interface and the expert knowledge components, we utilized the iterative design methodology. We integrated the two parts of the project from early on in the development stage, tested users, received feedback and continued to make changes throughout. We used an evolutionary[1] prototype during our intermediary testing and evaluations, which we continuously built upon throughout the entire developmental process.

5.1.1 Motivation

Speed and quality are the primary advantages of RAD, while reduced scalability and feature sets are the potential disadvantages [7]. Initially we did not know how we were going to design our system or how best to cater for the users' needs, so we did not have a concrete design/requirements plan from the beginning. We aimed to involve users as much as possible during the entire development process (both analysis to design). Over time we gathered more requirements and had a better understanding of the task at hand.

[1]The main goal with evolutionary prototyping is to build a very robust prototype in a structured manner and constantly refine it.

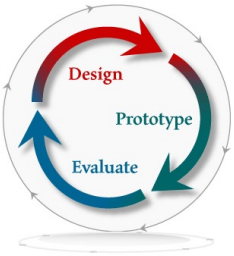

Figure 5.1: Iterative design process

RAD focuses on the development of a prototype that is iteratively developed into a full system (evolutionary prototype). Throughout the development, users test the functionality and usability of the system.

The main users we utilized during the process were:

Dr Aluwani Ndwambi

Dr Ndwambi is a family doctor at Garankuwa Hospital in Pretoria. She has studied Diabetes and has dealt with a number of patients at her practice. She gave us a lot of insight as to what happens during meetings with typical patients, how they should be talked to, how to approach sensitive topics and what to ask. Since we could not interact with any Diabetic patients or users from rural communities, Dr Ndwambi experience and knowledge served as a very vital resource .

Dr Audrey Mbogho

Dr Audrey Mbogho is the supervisor for this project. She has a speciality in Expert Systems and has dealt with similar projects before. She guided us throughout the project and we had frequent meetings with her. She gave us continuous feedback on our work and provided much needed direction.

Medical Students

Medical students at UCT have studied Diabetes in their 2nd year. We had 5th year medical students scrutinize our system on a few occasions, providing vital feedback from both a Diabetes-knowledge prospective and a usability prospective.

Normal Users

We used normal users with a non-medical background, this was to test the usability of the system and to give comments, suggestions and advice on what changes we should make.

Because of the time constraints we could not use our proposed 'target market' to test our system.

5.2 Knowledge Engineering

As part of the development methodology for an Expert System there needs to be an in-depth analysis process called knowledge engineering. This process includes the following phases: acquiring the data, representing the data in the system, inferencing and validating the data. Some Expert Systems also offer an explanation facility, so that any conclusions that are arrived at can be fully explained and justified to the user.

The four phases of this process applied in this context are be outlined below.

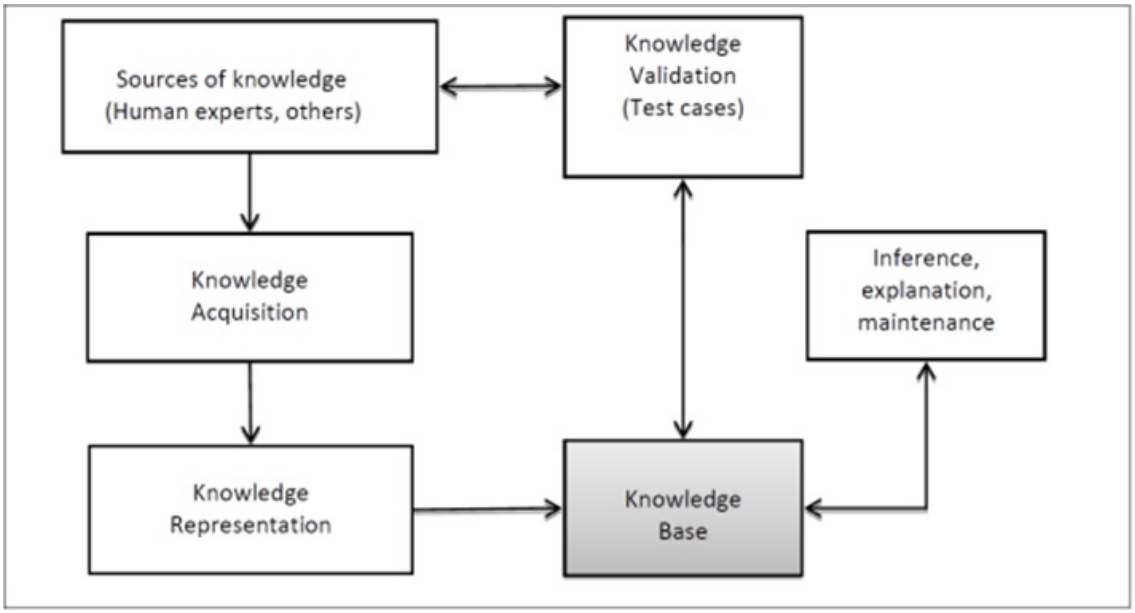

Figure 5.2: The knowledge Engineering Process

5.2.1 Knowledge Acquisition

During the knowledge acquisition phase, a few key resources were needed to gather accurate information on Diabetes. As software developers we do not possess enough knowledge in this domain, so we had to utilize the services of a professional Doctor to provide us with information. Dr Aluwani Ndwambi served as our personal point of reference throughout the project. We conducted a few interviews and meetings with her in order to gain a better understand of the disease and to figure out what approach to take with the development of the expert system.

We were able to grasp the concepts and definitions associated with the disease a lot easier after meetings with Dr Ndwambi.

The following information was discussed during our meetings:

- Diabetes definition.
- Causes of Diabetes.
- Symptoms of Diabetes.
- Complications that arise from Diabetes.
- Cultural beliefs associated with Diabetes.
- Medical consultation approaches.

Due to time constraints we could not use Dr Ndwambi as the only source of information. Thus, we made use of medical websites, journal articles and other on-line information.

5.2.2 Knowledge Representation

From the acquisition phase, a lot of vital information on Diabetes was gathered. The representation phase involves transferring the knowledge into the system. This is done by encoding the system with facts to be called upon during execution.This is one of the more difficult parts of the process as it involves carefully storing the information and knowledge imparted by the human expert in an appropriate manner without distortion.

Questions

The following are questions that a doctor would ask a patient in a typical on-on-one session. We implemented these in our system:

1. Demographic questions.
    (a) What is your name?
    (b) How old are you?
    (c) Are you male or female?
    (d) What is your race?
    (e) What is your weight?
    (f) What is your height?
2. Lifestyle questions
    (a) Do you smoke?
        i. How often do you smoke?
    (b) Do you drink?
        i. How often do you drink?

(c) Do you do any physical exercise?
    i. How often do you exercise?

3. Health questions.
   (a) Have you checked your blood pressure?
       i. What's your blood pressure?
4. General knowledge questions.
   (a) Do you know about Diabetes?
       i. Are you Diabetic?
   (b) Are any of your family members Diabetic?
   (c) Do you know what Insulin is?
   (d) Do you know what Glucose is?
   (e) Do you know what Gastroparesis is?

For the JESS code please see appendix A.2.

Symptoms

All the possible symptoms that could be experienced by someone who has Diabetes.The causes for the symptoms are stored as well, so that the system can explain to the user why they are experiencing them.

The following is the list of symptoms used in the Expert System:

- Fatigue.
- Frequent Headaches.
- Excessive Thirst.
- Excessive Urination.
- Nausea.
- Weight-loss.
- Irritability.
- Yeast Infection.
- Blurred Vision.
- Slow Healing Wounds.
- Numbness.
- Gum Infection.
- Extreme Hunger.
- Erectile Dysfunction.
- Gestational Diabetes.
- Dry Mouth.
- Abdominal Pain.

For the JESS code please see appendix A.5.

Diabetes Information

We have a comprehensive list of questions and answers concerning Diabetes. This is for the user to use to find out more about the Disease and the complications and conditions that come with it. A FAQ type set up was implemented, where answers we provided for the most common questions associated with Diabetes.

The following is the list of questions that were answered in detail by the Expert System:

1. What is Diabetes?
2. What are the risk factors of Diabetes?
3. What are the different types of Diabetes?
4. What are the symptoms of Diabetes?
5. What are the complications of Diabetes?
6. How can one prevent Diabetes?
7. How can one manage Diabetes?

For the JESS code please see appendix A.6.

5.2.3 Diction

Because of the assumed literacy levels of our target user group we had to make sure that basic English was utilized as much as possible. In sections where there are difficult words used, like "Insulin" and "Glucose" for example; we offer explicit definitions of the words to ensure that the user is able to understand.

5.2.4 Inferencing

This part involves writing the rules to act on different facts provided with the system and by the user. The inference engine is the 'brains' of the Expert System as this is where all the reasoning and logic takes place.

Feedback

The inferencing phase involved writing rules to give the users feedback depending on the input received from the user during the assessment.For example, if the user stated the following:

1. I am Diabetic.
2. I Smoke frequently.

The Expert System (code in Appendix A.1) would give the following feedback to the user:

"Smoking increases your blood sugar levels, this will make the disease much harder to control as well as increasing the chances of developing many Diabetes related complications over time."

Throughout the assessment the system is inferencing in the background, adding feedback to be shown to the user.

5.2.5 Knowledge Validation

Knowledge validation is a key aspect of the engineering process as there are often a lot of issues picked up at this level.The knowledge engineer designs and builds the system with the knowledge obtained from the human expert. Because of this transferal, there are often instances were there is misrepresented data. This happens because of a bias on the knowledge engineers side and/or simply because of poorly understood information. During validation, the information and the reliability of the system are tested to ensure correctness. In this project we had three iterations of user testing to test the reliability, accuracy and the usability of the system. The iterations are described later on in detail in the testing chapter.

Chapter 6

Design

6.1 System Requirements

The aim of this project was to build a web based Expert System. This system needs to interact with a user by asking a series of questions and prompting for user input back into the system. This system will need an interface for the user to interact with, input information and view system feedback. This information must be continuously processed in the background by a rule based engine that decides what to ask next and what conclusions to draw . As this is a web-based application, there will need to be an intermediate in-between these two core system components that will need to process and relay information between the interface and the rule based engine throughout.

The three system components are be explained below:

The Graphical User Interface

The user interface is used for mutual communication between the user and the system. The interface should be easy to use and very intuitive (as our main target market are illiterate users). Providing constant feedback to the user at all times as well as adhering to the standard design heuristics.

The Rule Based Engine

The rule based engine will contain all of the expert knowledge. This is where all the rules are stored, where all the factual data is stored and where all the results are processed.

The Intermediate

The intermediate will need to be placed in-between the user interface and the rule based system. This will serve as the link between the front-end and the back-end of the system.

6.1.1 MVC

This system is broken down into three distinct parts mentioned above(interface, rule based engine and controller). This adheres to the MVC architecture pattern, whereby the representation of the information is separated from the user's interaction with it. This allows the system to be modular and for the components to be independent of each other. Provided there is an API for them to communicate between one another. The Model View Controller paradigm has widely been adopted as an architecture for World Wide Web Applications [14].

The following are the three components.

View

The view represents the output to the user; in this case the web-based user interface. The aim ws to develop a desktop user interface with an additional mobile interface being a possibility initially. With this proposed architecture, these interfaces will serve as different views that will communicate with the same controller.

Model

The Model is where the logic is stored. In this case the rule based engine.

Controller

The controller sends commands to the model to update the models stae as well as to the associated views in order for them to change their presentation.

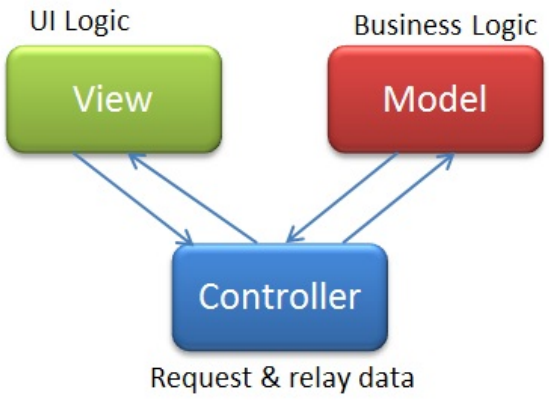

Figure 6.1: Basic MVC Architecture

6.1.2 Technologies Used

The following is a breakdown of the languages that were used in the development of this system:

Interface

- HTML - Hyper Text Markup Language.
- CSS - Cascading Style Sheets.
- JavaScript - Used for client side code.
- AJAX - Asynchronous JavaScript and XML Used for real-time dynamic data exchanges with the server.

Controller

- Java - Java was used for the servlet.
- JSON - Used to transfer information between the server-side code and the interface on the clients side.

Rule Based Engine

JESS was used as the rule based engine. JESS stands for Java Expert System Shell. This language was chosen because it can easily be integrated with Java.

Server

Apache Tomcat was used as the server environment. This enabled us to use a Java servlet to process commands and relay information between the front-end interface and the back-end rule based engine. Apache Tomcat is open source, cross platform and easily configurable.

6.2 System Architecture

The system is comprised of one index.jsp file, two java classes and a Rete object that represents an instance of the JESS rule based engine. The following diagram represents the classes and elements used in the system.

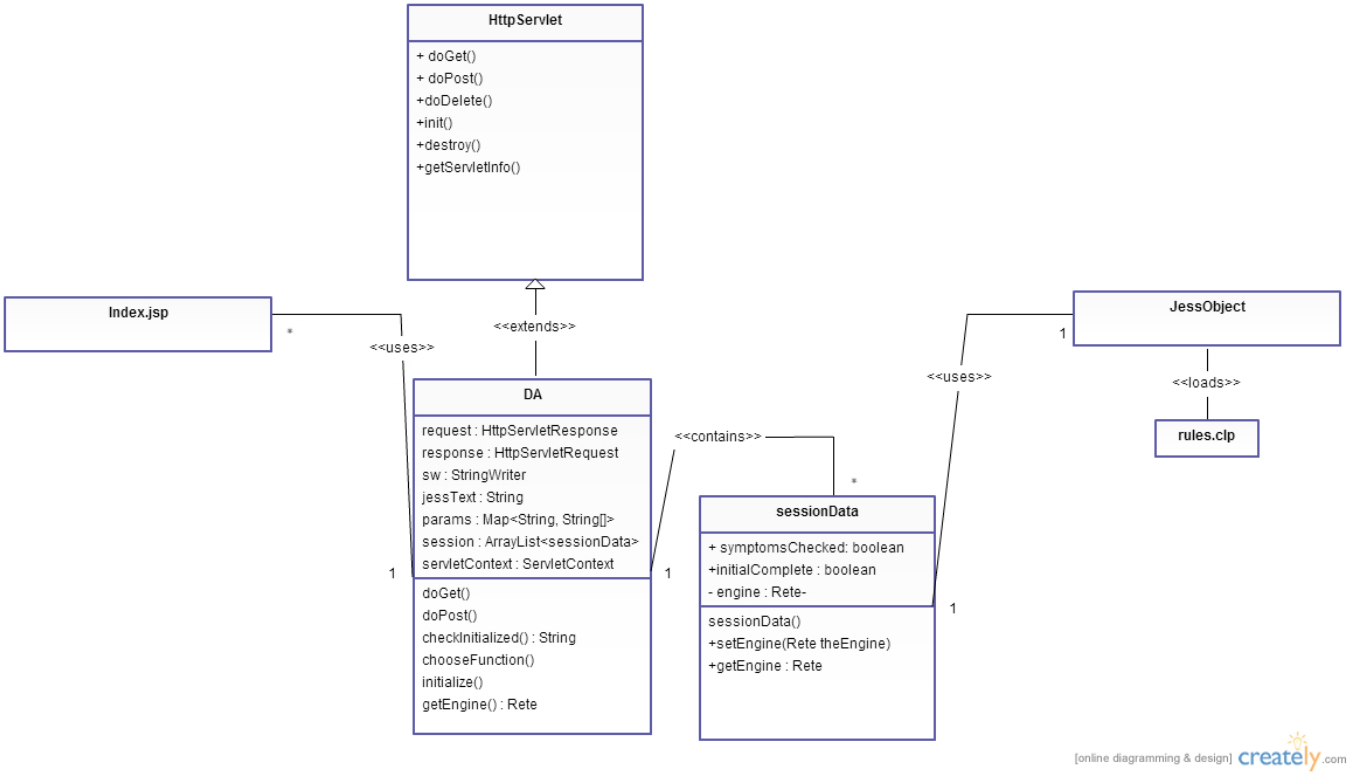

Figure 6.2: Class diagram of the Web-Based Expert System

Index.jsp

For the desktop interface one main .jsp file was used. The decision to only use one web page was made in order to minimize the time lost to continuous page reloading. All page the elements needed during the execution of the web application are loaded initially, with transitional effects changing the interface in real-time. Index.jsp communicates with the server with a simple AJAX call:

$.get('DA', {parameter : value}, function(responseText)
//insert code here; }

The response text sent from the server is in reply to the request made by the web page.

DA.java

DA.java is the servlet that was used to transfer data between the back-end and the front-end. As our web application is hosted on a server; this one instance of DA.java is shared through all the concurrent instantiations of the web application. In order for all users to have an independent session we had to make use of different session objects that are referenced with sessionID's. All the session objects are stored in an ArrayList on the DA.java object.

sessionData.java

This object is needed for session tracking. Because multiple users can be using the web application at the same time there needed to be some centralized way to manage the different sessions. This object kept data specific to that user session, so that every time a use makes a request, their specific session is changed accordingly.

JessObject

This is a Rete object. The Rete class is the central class in the jess Library, it is the rule engine itself. Each Rete object has its own working memory, agenda, rules, etc. This object is used to embed JESS in any Java application.

rules.clp

This file contains all the rules, logic and facts used in the rule based engine. When a new JessObject is created, it loads the rules.clp file from memory.

6.3 System Control Flow

The system has two main parts to it:

1. Diabetes Risk Assessment
2. Diabetes Information

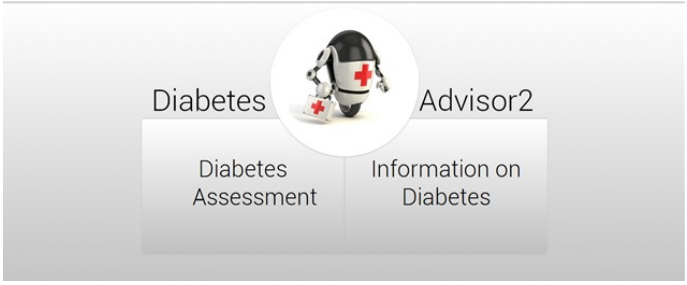

Figure 6.3: Initial screen

Diabetes Assessment.

The assessment is the core part of the Expert System. When the assessment begins, the user enters a question and answer session with the system (see Figure 6.8). After each answer is

given the Diabetes Percentage is updated based on the knowledge accumulated thus far, this percentage is displayed to the user (see Figure 6.9). At the completion of the assessment the user is notified of his risk of having/developing Diabetes.

The assessment is partitioned into three different sections:

1. General and demographic questions.
2. Symptoms.
3. Lifestyle questions.

After each of these phases, the system offers detailed feedback to the user, before progression to the next phase. Figure 6.8 shows the different states of the application.

Diabetes Information.

This section displays a set of 7 questions relating to Diabetes (mentioned earlier). The user selects the question and the answer along with any further options will appear on the screen. A sliding panel (activated on mouse hover) that contains the definitions of any difficult words that may occur is made available to the user.

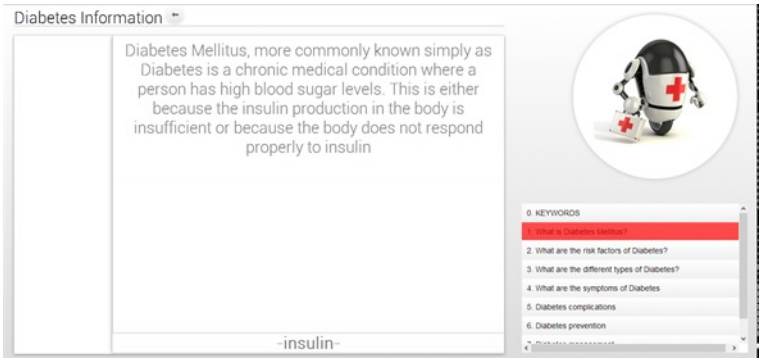

Figure 6.4: Diabetes Information.

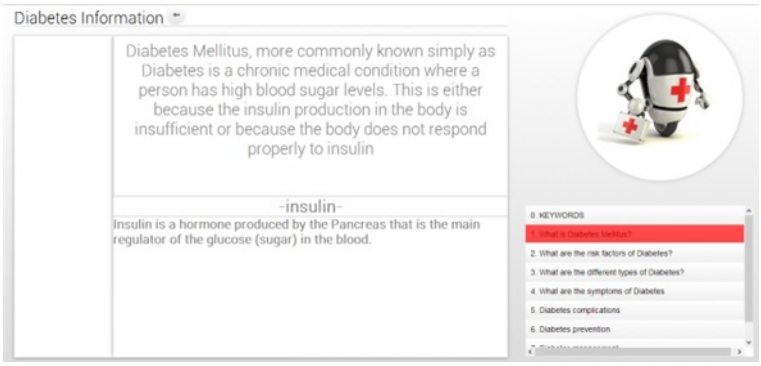

Figure 6.5: Diabetes Information with keyword sliding panel.

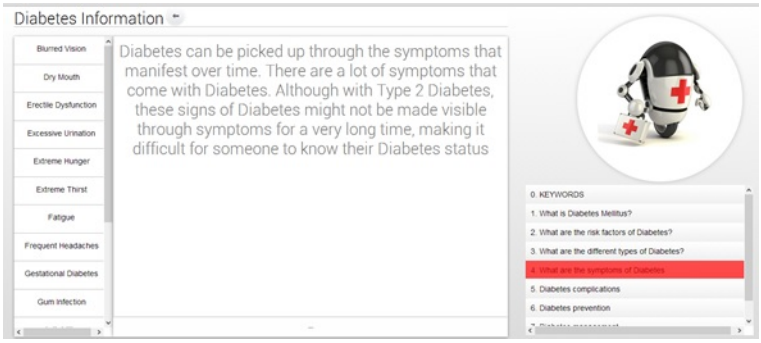

Figure 6.6: Diabetes Information displaying Diabetes symptoms.

Figure 6.7: Diabetes Information displaying symptom: Extreme Hunger.

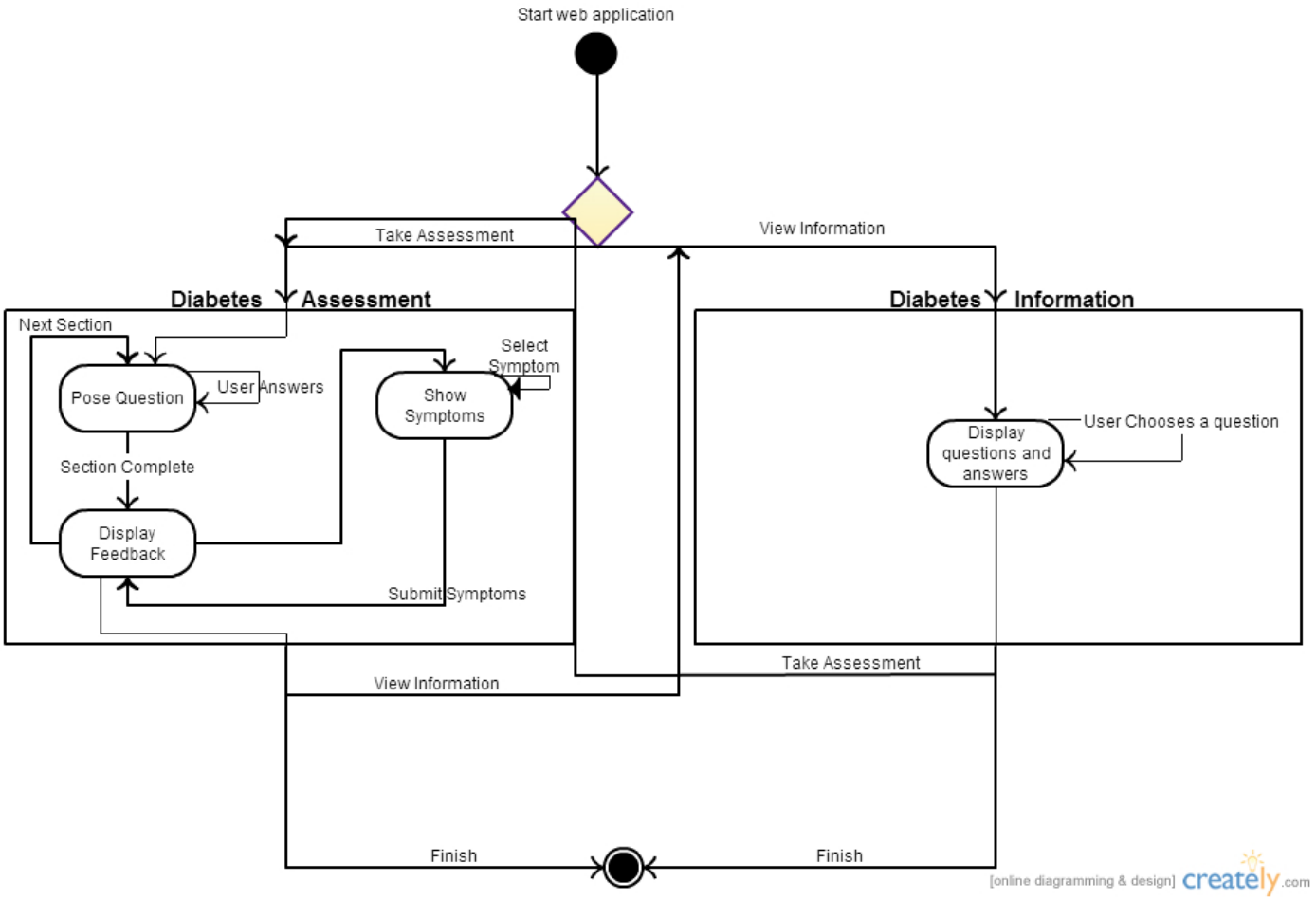

Figure 6.8: State diagram depicting control flow of application.

6.3.1 Modularity

The interface can only display the question that it is told to display, along with the components for the input the question is to accept. With this approach the interface is entirely dependant on the server's instructions before it can display anything to or accept any input from the user.We utilized JSON [1] objects to do this. The interface and the server transfer data between each other by embedding them in JSON objects. With this low coupling approach between components, the logic involved in the expert system can be modified without having to make any changes the interface and vice versa, adhering to the MVC paradigm.

[1] JavaScript Object Notation.

JSON

JSON stands for JavaScript Object Notation. It is a lightweight data- interchange format. A JSON object consists of a collection of name/value pairs. The reason we utilized JSON objects in our application is because it is completely language dependant. The conventions used by JSONs are familiar to both Java and JavaScript; the languages that were used in the server-side and client-side code respectively.

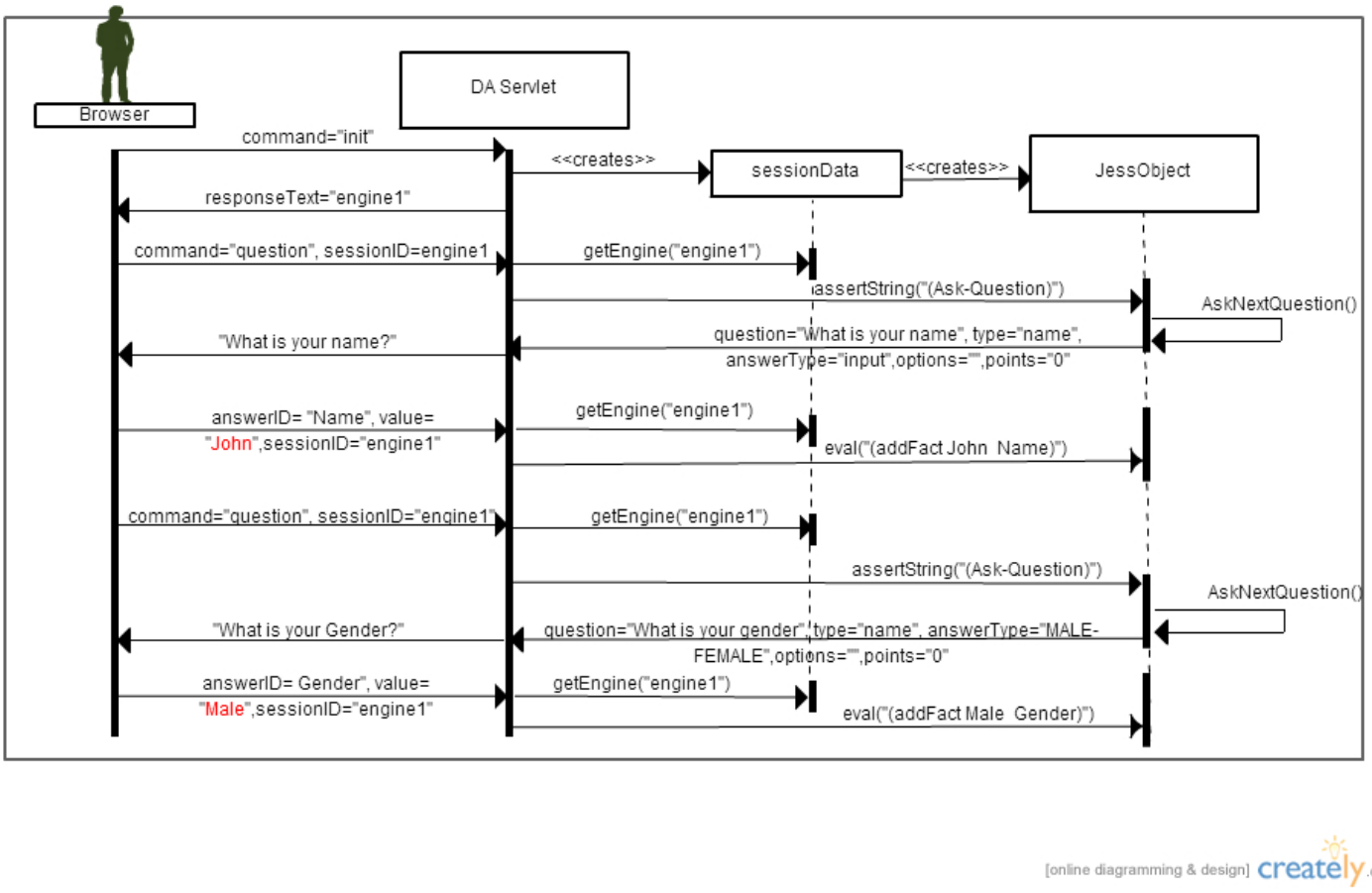

Figure 6.9: Activity diagram showing an example of inter class communication.

The above diagram shows the communication between the front-end interface and the back end server. On page load, the server gives the particular session a session ID, this is for session tracking. Each session has its own sessionData object as well as a JessObject. Each interaction from then on between the front-end and the server will include that particular sessionID (in this case the sessonID is "engine1") as a reference, so the server can use the correct sessionData object. This sessionID is incremented by 1 (i.e engine2, engine3, engine4 etc.) for each new subsequent instantiation. The above diagram also shows the data exchange in the form of JSON objects between the browser and the server. The user input is highlighted red.

6.3.2 Questions and Answers

The user's answers to the question are sent back to the rule based engine immediately after they are entered on the web page. This answer will then fire certain rules and also update the users percentage score. For example: If the user states that they do not smoke, the following rule will assert the appropriate feedback and ensure that the expert system does not ask how often the user smokes. On the contrary, if the user states that he does smoke, the expert system will proceed to ask how often the user smokes. An illustration with screen shots is provided below in Figure 6.9.

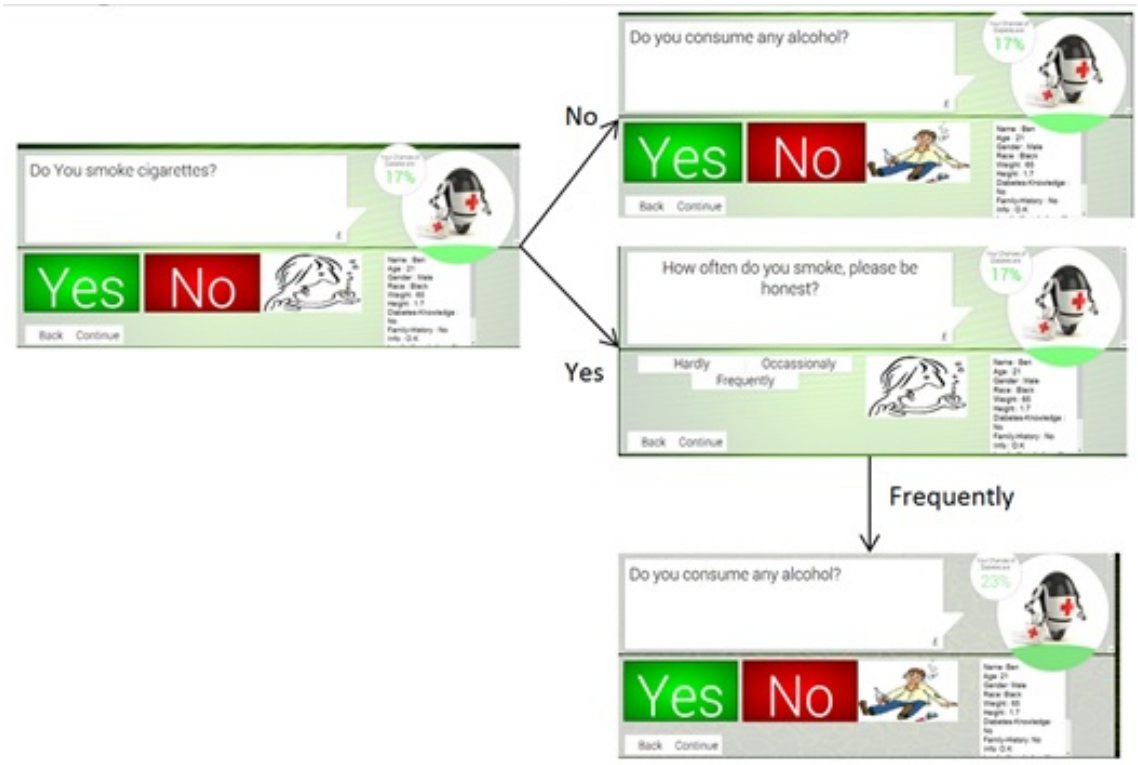

Figure 6.10: Control Flow of Expert System.

The following snippet of JESS code shows how the structure was incorporated for the above questions.

(Question (section Lifestyle)(type "Smoke")(text "Do You smoke cigarettes?") (answerType "YES-NO")(order 16))

(Question (section Lifestyle)(type "Smoke-Frequency")(text "How often do you smoke, please be honest?") (answerType "OPTIONAL") (options "Hardly-Occasionally-Frequently") (order 17))

(Question (section Lifestyle)(type "Alcohol")(text "Do you consume any alcohol?") (answerType "YES-NO")(order 18))

6.3.3 Diabetes Risk Percentage

During the assessment, the user's percentage is updated after each input is received.

Figure 6.11: The user's Diabetes Risk percentage.

Only certain input will have an effect on the users Diabetes risk percentage. For example the BMI rule (see code in appendix A.1) calculates the users BMI and then increases their points based on the weight-classification (either underweight, overweight or Obese) category that they are placed in.

If the user inputs the following:

1. Weight = 200 Kg
2. Height = 1.5 M

The calculated BMI would be 89 kg/m^2, placing them in the Obese category. According to the rule, their Diabetes Risk points would thus increase by 20 pts, and the interface would display the appropriate feedback to the user. If the user is classified as Overweight, their points increase by 10 else if placed in any of the remaining two categories, their points do not change.

The user input that could possible affect their risk percentage is as follows:

- BMI.
- Diabetic family members.
- Pregnancy status.
- Drinking Frequency.
- Smoking frequency.
- Blood pressure level.
- Exercise frequency

Point justification

The percentage calculation was not based on any medical guidelines as none were available for this purpose. However, it serves to demonstrate how a quantitative risk evaluation can be incorporated into the system. Only minor programming changes need to be made when the guidelines are known. This is a prototype system and the results should not be seen as completely accurate but rather experimental.

6.3.4 Symptoms

The symptoms section of the assessments, requires the users to select which symptoms (5.12) they are currently experiencing. Figure 6.10 displays the initial screen in the symptom selection section of the assessment.

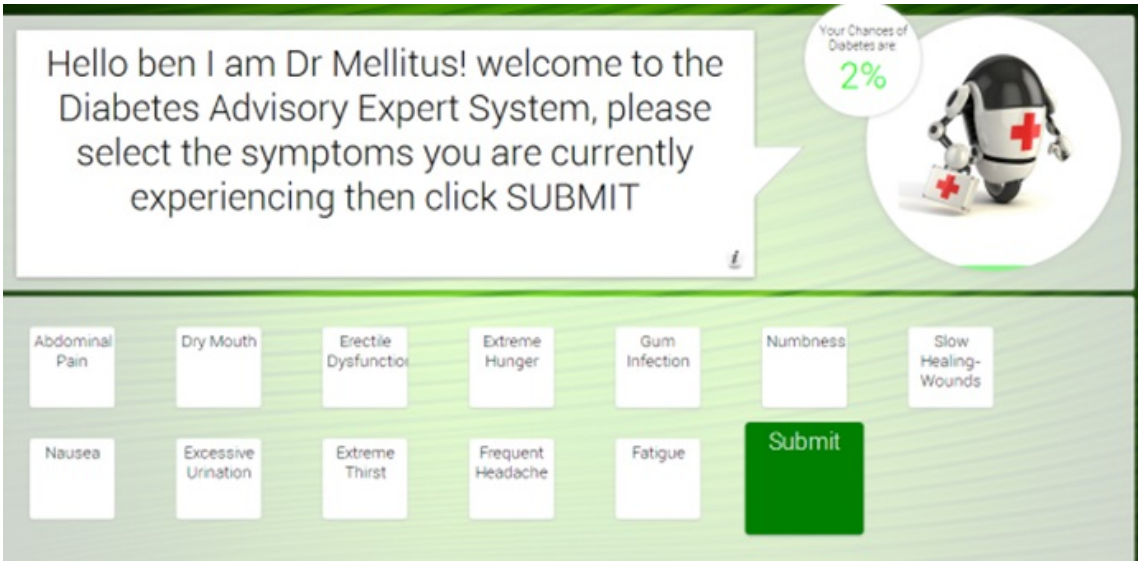

Figure 6.12: Symptom selection.

6.3.5 Symptom Selection

The system explains the symptom to the user, as the user hovers over the symptom as seen below in figures 6.11 and 6.12. This is to help the user relate more to the symptom, also if the user does not understand the words used in the symptom description. As an example the explanation for 'Abdominal Pain' and 'Numbness' are shown below.

Figure 6.13: Symptom explanation for Abdominal Pain.

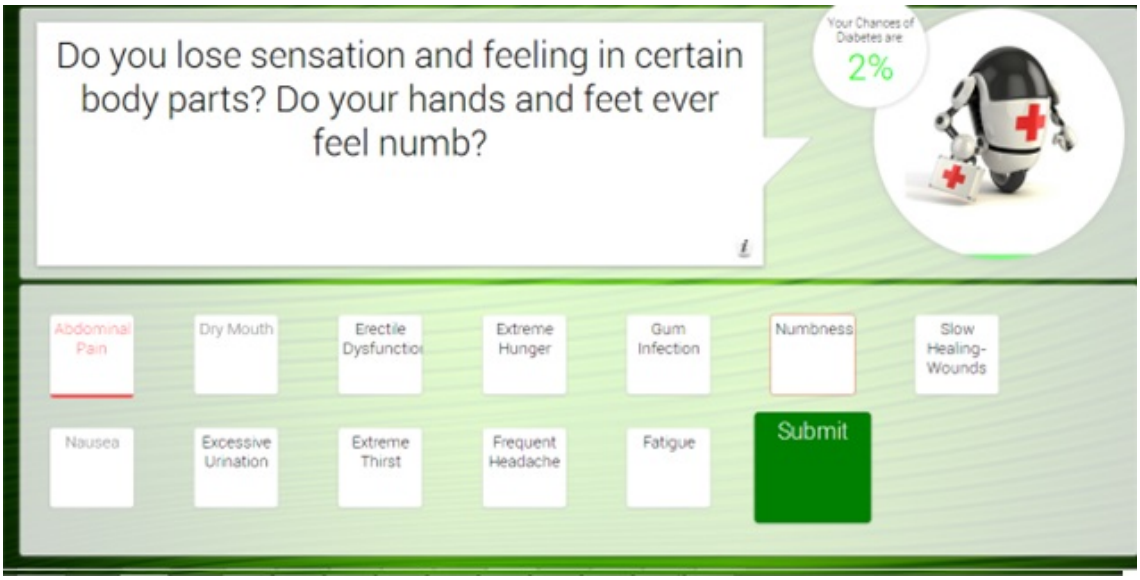

Figure 6.14: Symptom explanation for Numbness.

6.3.6 Symptom Feedback

The User is expected to select the symptoms that he is experiencing and then click on the submit button. After the submit button is clicked, the list of experienced symptoms are explained to the user, in the context of Diabetes.

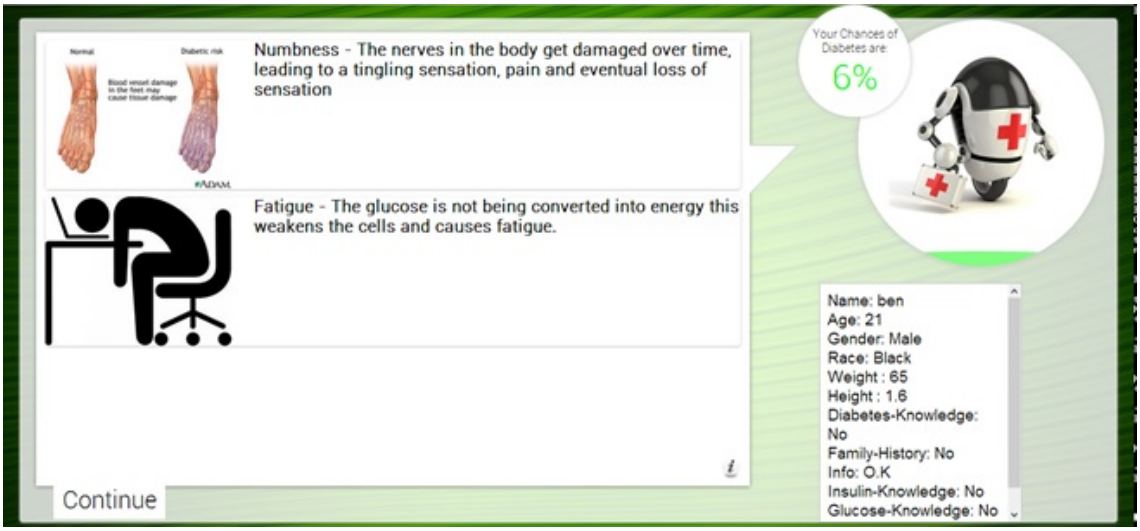

Figure 6.15: Symptom reason feedback in the context of Diabetes.

After the user submits the symptoms he is currently experiencing, his Diabetes risk percentage is updated.

6.3.7 Symptom Points Assignment

The symptoms are assigned risk points depending on their severity. Some symptoms are more severe and a lot more specific to Diabetes than other symptoms. For instance, erectile dysfunction and slow healing wounds will have a higher association with Diabetes than fatigue, frequent headaches and irritability. With the latter being much more general.

The symptoms and their associated Diabetes risk points are shown below..

Symptom	Points
Extreme Thirst	10
Excessive Urination	10
Erectile Dysfunction	10
Gestational Diabetes	10
Gum Infection	8
Extreme-Hunger	8
Yeast Infection	8
Abdominal Pain	8
Slow Healing Wounds	8
Dry Mouth	7
Nausea	5
Frequent Headache	4
Numbness	4
Blurred Vision	3
Fatigue	2
Irritability	1

Table 6.1: Symptoms and associated Diabetes risk points

For the code please see appendix A.4

6.3.8 Feedback

The Expert System offers feedback after each of the three stages of the assessment, as well as a final assessment that contains the users overall Diabetes Risk Assessment percentage. Along with an explanation of what the percentage means. For each of the questions asked, there is associated feedback displayed to the user, depending on the users answer.

For example the system checks if the user knows what the following terms mean:

- Diabetes
- Insulin
- Glucose
- Gastroparesis

If the user is unfamiliar with these terms, their respective explanations will be displayed on the feedback screen.

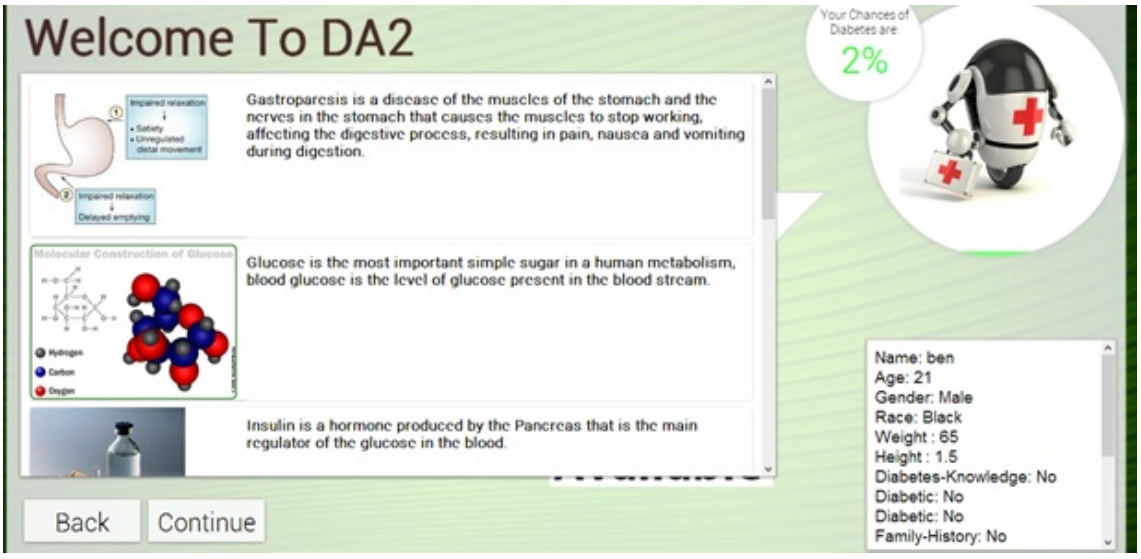

Figure 6.16: Feedback displaying unknown terms to the user.

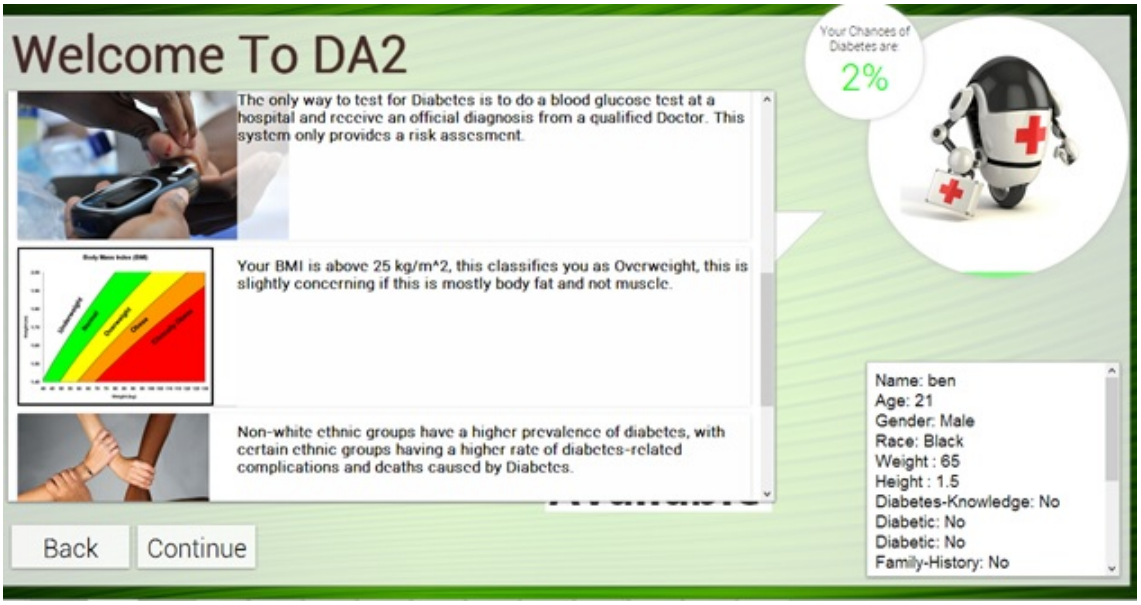

Figure 6.17: Feedback displayed after stage 1.

Figure 6.17 (above) displays the feedback the expert system provides the user based on their answers in stage 1 of the assessment. In the bottom right corner of the screen you can see the information relting to the user. Figure 6.18 (below) displays the feedback the expert system provides the user based on their answers in stage 3 of the assessment.

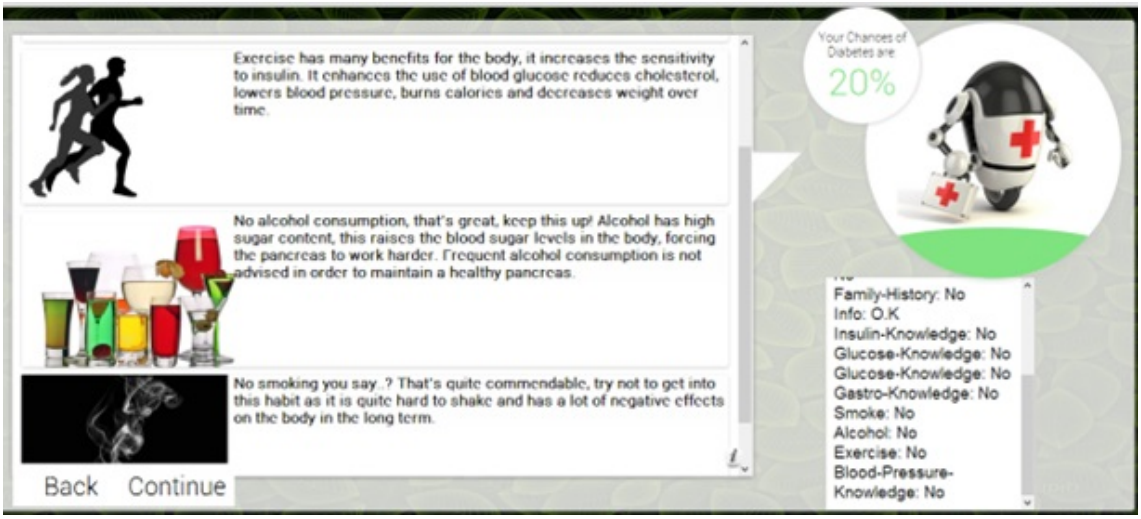

Figure 6.18: Feedback displayed after stage 3.

6.3.9 Final Feedback

On completion of the assessment the Expert System displays the overall Diabetes Risk percentage of the user. This is displayed along with a message relating to the risk percentage. The following table gives the messages displayed and the percentage ranges .

Percentage Range	Message
100 > 90	You have an extremely high risk of Diabetes!!! This a great concern and should be dealt with immediately you should go to the nearest hospital and seek professional medical attention as soon as possible. Only after blood glucose tests, can you be officially diagnosed with Diabetes
90 > 75	You have a very high risk of Diabetes! This should be viewed as a great concern and should be dealt with immediately you should go to the nearest hospital and seek professional medical attention as soon as possible. Only after blood glucose tests, can you be officially diagnosed with Diabetes
75 > 50	Your chances of getting diabetes is greater than 50%, this is higher than the average person and should be checked with a medical professional.
50 > 40	Your risk of Diabetes is around the 50% region, this should be seen as a concern and should be taken as a warning sign.
40 > 30	You have a low risk of Diabetes, it should not be anything to worry about, provided you continue to eat well and live a healthy lifestyle.
30 > 0	You have a very low risk of Diabetes, this is because of your lack of threatening risk factors, symptoms and your decent lifestyle habits, please do continue and remember to eat healthy and keep active. Diabetes cannot be cured but it can be prevented!

Table 6.2: Final messages for the different Diabetes ranges.

For the code please see Appendix A.5.

Along with the result of the assessment, the user is reminded that this system is only a prototype and that they should seek professional medical help if they would like to find out their official Diabetes status. This is to ensure that the user is aware that the advice and feedback given are not official and entirely accurate. On completion of the assessment the user can do any of the following:

- Restart the assessment.
- View Diabetes information.
- View nearby clinics.

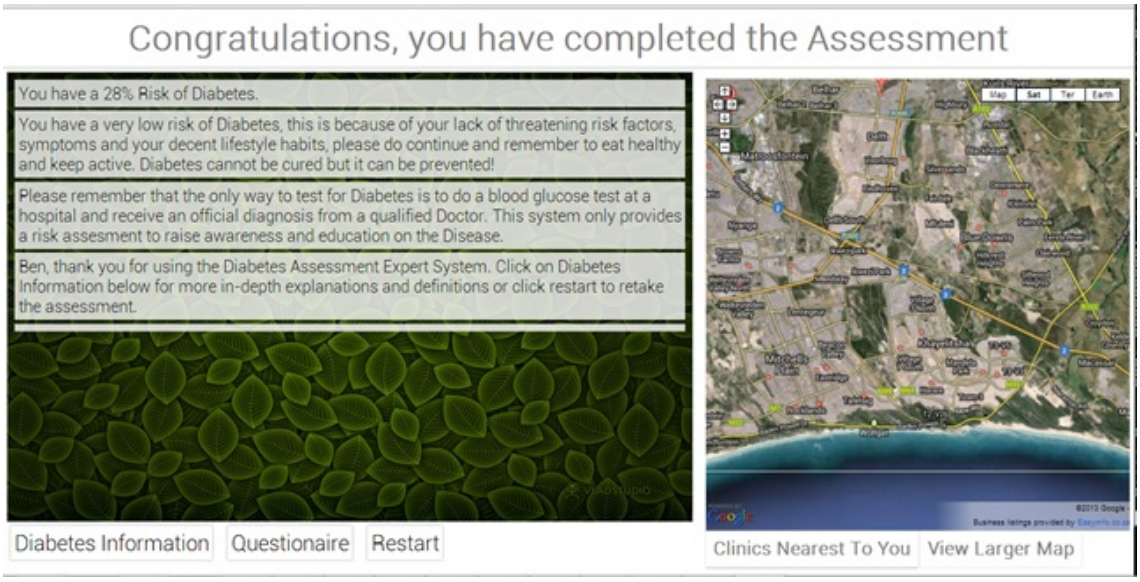

Figure 6.19: Feedback displayed on completion of assessment.

Chapter 7

User Testing

We performed three official user tests during the development of the web-based expert system. Along with these official tests we received continuous feedback from our personal doctor, Dr. Ndwambi and our supervisor Dr. Audrey Mbogho. Because of the nature of our project; user testing and evaluation was extremely important. It was imperative that we received user views and feedback throughout the developmental phase. We relied heavily on the feedback from the users that were involved.

As mentioned before the project has two main aspects:

1. Expert System.
2. User interface.

Because of our early integration of the two components, these two aspects of the system had to be tested concurrently. The user testing for the interface is expanded upon in the HCI component of this project, done by Hallatadzi Matidza.

Within the expert system the following aspects had to be tested:

Knowledge Base
: The knowledge base contains all the information gathered during the knowledge acquisition phase of the Knowledge Engineering process. This is comprised of the explanations of what Diabetes is, what the types of diabetes are, what the symptoms of Diabetes are etc.

Inferencing
: The inferencing information is the advice, feedback and conclusions dynamically made by the system that are related to the user input entered in the assessment. This is analogous to being in a consultation session with a doctor and is the type of realistic interaction we were trying to imitate.

Expert System
: The overall usability and functionality of the Expert System had to be scrutinized. This

includes both the assessment and the information portal. During our tests we asked the users to rate the overall system as well as to give us feedback, comments and/or suggestions for improvement.

7.1 Approach

Because we wanted to gain as much out of the process as possible, we took a very personal approach to the user testing, with the aim of gathering qualitative results from the user interaction with the system. We wanted to understand what the users felt about the system and gain insights into their opinions of it. With out first iteration we tested each user separately and opted for the Think aloud method [9] to gain more insight into their thought processes.

7.1.1 Think aloud method

Think aloud method is a behavioural based evaluation technique [9]. With the think aloud method, we encourage the user to speak their thoughts while they perform the tasks. This is done so that we can understand:

- What the users are trying to do.
- How the users understand/interprets the system.

This approach provides the testers with insight during the process. The testers are able to gain information about cognition and emotions of the user while they perform a task. The user is instructed to articulate what they think and feel while interacting with the prototype. We explained the aims of the system, the purpose of the project and the reason why they were needed to test the system. A key assumption that we made was that conversation during testing would not have a negative affect on the results. To ensure this we tried to make the users as comfortable as possible.

With the second iteration we were testing the knowledge used in the system, for this reason we needed to test medical students because of their knowledge of Diabetes.The benefit of this was that with the medical students we were able to test both the knowledge base and the usability of the system at the same time. For this iteration we opted for group testing. We wanted the users to discuss amongst each other while they used the system. We requested that each user bring their own laptop to the testing venue. Unfortunately not everybody was able to. As much as this was unintended, it enhanced the testing as it created a more collaborative process were two users would share one computer and communicate throughout, also known as the Constructive Interaction Method [11].

7.1.2 Constructive Interaction Method

This approach to user testing lets two or more users work together during the testing. This is done so that their conversation can be monitored. [11] states that this technique is more 'natural' than the think-aloud method. We noticed that introduced a much more comfortable setting as the group

of users that we used were all familiar with one another.

With the final iteration we tested five users, our doctor, two normal users and two medics. The four students that we used were all users from previous tests. The reason we did this was because they had already been involved with our application. They were able to assess the progress that we had made from the previous round of testing because they were familiar with the system.

7.1.3 Observation and recording

Throughout the user testing process we observed our test subjects closely and we took down written notes of their interactions with the system along with the comments they made. We had the users fill out a questionnaire on completion of the testing.

7.1.4 Questionnaires

We used on-line Google forms to construct our questionnaires and aggregate our results. The users filled out these questionnaires on either a laptop or a tablet that we provided. We made use of an odd- numbered 5 point scale, otherwise known as a Likert Scale[10] so that we could easily quantify our results. This scale had the following values:

- 5. Strongly Agree
- 4. Agree
- 3. Neutral
- 2. Disagree
- 1. Strongly Disagree

This 5 point scale fairly represents the different responses that a user could have for a statement, with the neutral option available to cater for an opinion that is neither negative or positive. We did not use any statistical means to measure the significance of the results from the questionnaires. The numbers used in the scale are simply representative of the corresponding verbal statements.

7.2 Iterations

There were three official iterations of user tests, they shall be outlined below.

7.2.1 Iteration 1

With the first iteration we tested 7 users with our initial prototype. Because we were using the RAD approach we had a fully functional prototype (high fidelity) that was already running on a server (`www.peoplesoft.cs.uct.ac.za:8080\DA`).

No.	Question
1	The information provided by the expert system on Diabetes is comprehensive?
2	The information provided by the Expert System on the various symptoms is comprehensive?
3	All the questions asked by the Expert System are relevant?
4	The Expert System provides continuous feedback throughout?
5	The System is easy to use?
6	Which task did you have any problem with?
7	Do you find this system useful, why?
8	Any suggestions on how the Expert System can be improved?

Table 7.1: Iteration 1 Questionnaire

7.2.2 Results

Multiple choice

Question No.	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	2	2	3	-	-
2	2	4	1	1	1
3	1	3	2	1	-
4	-	-	2	4	1
5	1	4	1	1	-

Table 7.2: Summary of results

Question No.	Entering Information	Reading instructions/question	Navigating the system	Understanding the system
6	1	4	4	1

Table 7.3: Which task did you have any problem with? - users could select multiple answers.

Open Ended

7. Do you find the system useful, Why?

The following are paraphrased responses to the question:

- The system is useful for people that do not know anything about Diabetes.
- The system is useful as it can relive doctors off of trivial duty to handle more serious matters.
- It is a very useful tool to learn about Diabetes.

8. Any suggestions on how the Expert System can be improved?
Two users stated that we should include more instructions.

7.2.3 Discussion

This iteration gave us a lot of insight as to how useful and usable our system was. After the testing, we decided to use more pictures and photos to stimulate users' interest and also to enhance their understanding of the explanations/definitions used in system. We used simpler English and tried to make our instructions as straight-forward and concise as possible. Also, at this stage of development we had not accomplished a high level of modularity between the interface and the Expert System; all of the information displayed on the screen was hard-coded in the front-end code. We decided to go for a more modular approach, and separate the two components entirely, making the interface 'dumb'. With this approach the interface can be used for any type of expert system, without having to be modified significantly.

7.2.4 Iteration 2

With the second iteration we had separated the expert knowledge from the user interface and had two independent system components. At this point we had a roughly complete end-to-end system that included both the assessment and the information functionality (refer to figure 6.3) present. We did not have pictures available for all areas as of yet, so the default image (Appendix B.21) was shown in a lot of cases. This iteration was primarily focused on getting approval and feedback from the medical students. We tested 9 5th year medical students from UCT during one session, in a conference room set-up.

No.	Question
1	The information provided by the expert system on Diabetes is easy to understand?
2	The information on Diabetes provided by the system is useful?
3	The advice provided by the system is correct and useful?
4	The symptom feedback provided by the expert system is easy to understand?
5	The symptom feedback provided by the expert system is useful?
6	The questions asked by the system are relevant?
7	This assessment considers all the possibilities that a Doctor would during an interview with a patient?
8	Are there any other questions that should be asked in this assessment?
9	Would you recommend this system to a person wanting to find out more about Diabetes and their Diabetes status?
10	This Expert System has the potential to raise Diabetes awareness in South Africa?
11	Any further comments?
12	Please give an overall rating for the Expert System?

Table 7.4: Iteration 2 Questionnaire

7.2.5 Results

Multiple Choice

The results in tabular form are below (for the equivalent graph illustration please see appendix B)

Question No.	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	2	7	-	-	-
2	4	3	1	-	1
3	2	4	3	-	-
4	2	4	2	-	1
5	2	5	1	-	1
6	4	4	-	-	1
7	1	4	4	-	-

Table 7.5: Summary of results Questions no. 1-7

8. Are there any other questions that should be asked in this assessment

The following suggestions were made.

- Ask users about their Diet.
- Ask users about their Cholesterol level.
- Be more specific with how you quantify alcohol intake, smoking and exercise - it is currently very subjective.

Question No.	Yes, Definitely	Maybe	No, its not good enough
9	8	-	1

Figure 7.1: Would you recommend this system to a person wanting to find out more about Diabetes and their Diabetes status?

Question No.	Yes, Definitely	Maybe	No, its not good enough
10	8	1	-

Table 7.6: This Expert System has the potential to raise Diabetes awareness in South Africa?

11. Any further comments?

The following comments were given:

- Include diagrams to explain what insulin is and what role it plays in the body, maybe animated illustration.
- There were spelling errors in some definitions.

- This is a very excellent idea, will be very useful with someone without medical experience.
- The system is a bit informal at times.

Question No.	Excellent	Good	Average	Bad	Poor
12	1	5	1	-	-

Table 7.7: Please give an overall rating for the Expert System? (For unknown reasons, 2 medics did not fill in this question.

7.2.6 Discussion

The user testing with the medical students was extremely useful. We were able to assess if the information used in the Expert System was correct and if our explanations and percentage calculation were accurate. We received positive reviews overall with a lot of feedback.

It was strongly suggested that we utilize a more descriptive manner of the displaying information, as opposed to just text. There were also a lot of spelling errors at this stage. This is because the IDE[1] that the JESS code was developed in, did not have a spell check, so a lot of errors went unnoticed; this was fixed before the final iteration. Some of the students commented about the process of revealing personal 'sensitive' information (like weight, age etc.) to a computer. This is a very valid point that was raised, although it could have also been due to the fact that the students were surrounded by other people and thus felt a bit self conscious. The students also wondered if the information was being stored permanently on the server and were concerned about the privacy of their data. We explained that no data is kept after the assessment and decided to incorporate this explanation into our system as well. It is likely that future users could have similar concerns.

We were pleased with the response from the medical students.An important suggestion was made to use the same source for all medical information because a few students stated that some of the information did not sync well with the rest. We were advised to make use of *Medscape*[2]. We were also told to only include information that was directly involved with Diabetes and relevant.

After the user testing, we made a few more changes to the application.

- Corrected all the spelling errors.
- Included more keywords in the Diabetes Information section. In order to ensure the user has no difficulty understanding any explanations made by the Expert System.
- Completed picture usage in all applicable areas.

[1] Integration Development Environment - The Eclipse Juno was used with the JESSDE installed.

[2] Medscape - `http://www.medscape.com/` - is a reliable online medical information resource that coves a wide range of topics.

- Included the keyword Display panel in the Diabetes Information section (refer to figure 6.5).
- Corrected bugs with regards to the percentage update mechanism.

With regards to adding more questions to the Expert System like diet and cholesterol, these questions are not easy to pose on a computer. Diet is a very tricky to analyse with multiple choice questions, because there is a lot too ask.Cholesterol on the other hand are measured by blood tests. With the users that the system is targeting it is very unlikely that they will have ever measured their cholesterol. These are important aspects in Diabetes assessments and should be taken into consideration in future work.

7.2.7 Iteration 3

For the third and final iteration of user testing we tested 5 users. One was our doctor, 2 were normal students (without a medical background) and the remaining 2 were 5th year medical students. All four of the students had tested the system previously and were aware of the progress that was made. At this stage of development, we had completed the majority of the requirements. There were still a few features that we had not implemented, but this will be discussed in future work.

No.	Question
1	The information provided by the expert system on Diabetes is easy to understand?
2	The information on Diabetes provided by the system is useful?
3	The symptom provided by the Expert System is easy to understand?
4	The symptom feedback provided by the expert system is useful?
5	The questions asked by the expert system are relevant?
6	Would you recommend this system to a person wanting to find out more about Diabetes and their Diabetes status?
7	This Expert System has the potential to raise Diabetes awareness in South Africa?
8	A person with basic computer skills can use this system?
9	Please give an overall rating for this system.
10	What is your opinion on the length of the assessment?
11	Any further comments?

Table 7.8: Iteration 3 Questionnaire

7.2.8 Results

Multiple-choice

The results in tabular form are below (for the equivalent graph illustration please see appendix B)

Question No.	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	3	2	-	-	-
2	4	1	-	-	-
3	3	2	-	-	-
4	3	2	-	-	-
5	4	1	-	-	-
8	1	2	2	-	-

Table 7.9: Summary of results

Question No.	Yes, Definitely	Maybe	No, its not good enough
6	5	-	-

Table 7.10: Would you recommend this system to a person wanting to find out more about Diabetes and their Diabetes status.

Question No.	Yes, Definitely	Maybe	No, its not good enough
7	3	2	-

Table 7.11: This Expert System has the potential to raise awareness in South Africa?

Question No.	Excellent	Good	Average	Bad	Poor
9	1	2	2	-	-

Table 7.12: A person with basic computer skills can use this system?

Question No.	Excellent	Good	Average	Bad	Poor
9	2	3	-	-	-

Table 7.13: Overall rating for the Expert System?

Question No.	Too long	Sufficient	Too short
10	-	5	-

Table 7.14: Opinion on the length of the assessment?

11. Any further comments?

The following comments were given:

- The system has great potential but some credibility is needed for the information provided and the algorithm used to tally points.
- At the end of the assessment there should be a display of the interpretations of all the percentages, so the user knows where 'they stand' in relation to the overall scale.
- The application is a bit too serious.
- Information is easy to understand, especially for someone who does not know about Diabetes.
- The Diabetes Information display is good.
- Consider using voice commands as well as voice recognition

7.2.9 Discussion

The results from the final iteration were very positive. All of the users were pleased with the progress from the previous iterations and they were still able to provide more feedback and suggestions. Both the medical students and the non-medical students gave positive reviews of the application, approving the user interface, the knowledge base and the inferencing. The users felt that the duration of the assessment is sufficient and that the system is useful, with all the users stating that the web based expert system is above average (Figure 7.2).

For users to take the system seriously. Some sort of reference or endorsement is required, as mentioned in the user comments. Ideally this would have to be some sort of established medical institution/body.

Issues during testing

During the testing there were occasions were the application would encounter problems , but this is because of some issues with the communication with the server. This was a minor issue that did not impact the testing process or the results.

From the user testing the following was noticed:

- Users may be wary of disclosing personal information to a computer
- Users may not have accurate information on hand, like their height.
- Users may take offence with certain feedback received from the Expert System. For example, being told you are obese by a computer.
- Users maybe either take the system too seriously, this wasn't experienced during testing, but it is a possibility. Especially when the users are not familiar with the system and the background off the project.

- Users might totally disregard the information received from the system because it is not a qualified doctor.

7.3 Summary

The user testing process was a success overall, there was a lot of insight and value gained from testing our application. 17 different people were tested overall in the three iterations, with the majority pleased with the application. The majority of the users stated that this application has the potential to make an impact in the developing world but the general feel is that it is not easy for someone with basic computer skills to manoeuvre around the system effortlessly (see Appendix B.18). The length of the assessment was regarded as sufficient, which is important because with long tedious assessments the user can begin to lose interest and attention over time, affecting the overall results of the assessment. Some users stated that the application should be made more interactive and 'fun' in an attempt to engage with the user more.

All of the users that were tested are very computer literate and also fairly educated (as they are currently pursuing degrees at UCT), so these results only show the perceived usefulness and impact that the system would have on the target market. The results still serve as a good indication that this system would be of good use. It would be very interesting to see actual results by testing the system in rural communities. Where there are people with limited knowledge of Diabetes and also possibly only have basic computer skills.

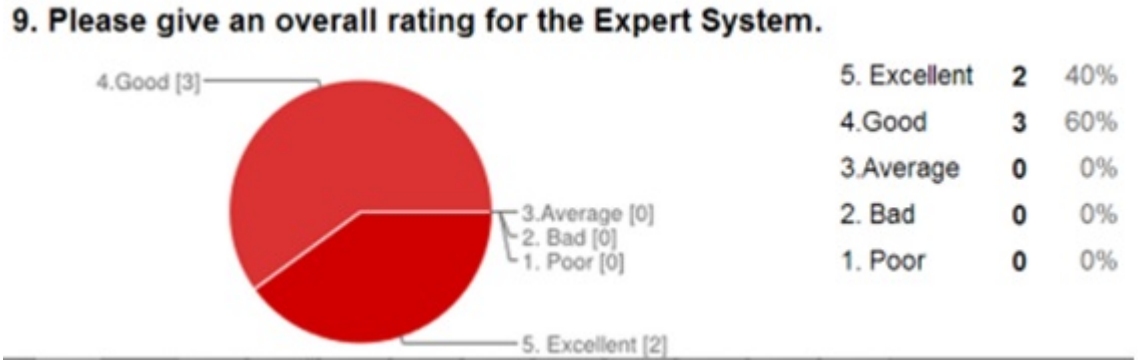

Figure 7.2: Question 9.

Chapter 8

Conclusion

The aim of this project was to develop a web based expert system that offers users with a Diabetes risk assessment and comprehensive information on Diabetes. With the limited time available for the duration of the project, a Rapid Application Development (RAD) methodology was adopted which focused on creating functional software by using an iterative design approach. We had a high user involvement throughout the project and successfully went through three iterations of user testing with two different categories of students (medical and non-medical) to assess the different facets of the System. We had a professional doctor on hand to assist with the medical aspects of the system, throughout the development phase.

We used a high fidelity, evolutionary prototype during the user tests and this was built upon throughout the project. During the three iterations of user testing we incorporated different evaluation strategies in order to obtain the best results.We made observations and documented any comments and suggestions made by the users during the testing sessions. After each of the test iterations we did our best to take the users' suggestions into consideration and keep our target market in mind throughout.

The results of the tests were extremely useful. A lot of the time the users noticed issues that we as the developers were not aware of This gave us a lot of insight to how to develop a system from a user's perspective. Not all of the suggested changes could be implemented due to time constraints. These shall be discussed in future work. During the third and final iteration a lot of positive feedback was received from the users, with all of the users stating that the system could have a positive impact on the developing world with regards to raising Diabetes awareness.

8.1 Accomplished objectives

A Diabetes risk assessment calculator was implemented. This gave the user an assessment of their chances of developing Diabetes, in the form of a percentage calculation. Unfortunately we were not able to test the results on actual Diabetics because of the time constraints and potential ethical clearance delays. The reviews from the user testing were positive and although the calculations used are by no means *accurate*, the framework implemented in this system could be further improved upon by more in-depth research into this field.

The application provides in depth information on Diabetes. Along with the information, there is an ever present display dedicated to explaining any words or terms that the user might have difficulty in viewing. From the user testing with the medical students and the assistance from the Doctor, we believe that we have incorporated the core terms and definitions that are associated with Diabetes. The test results show that the information provided was easy to understand and useful (see Table 7.9). With all the users stating that they would further recommend this system to someone who wants to find out more about Diabetes (see Figure 8.1).

All of the users that tested our system are computer literate. It would have been ideal to test the system with users who only have basic computing skills. The users gave positive reviews with regard to the usability of the system, but the general feeling is that it might not be easy for someone with basic computer skills to use the system without difficulty.

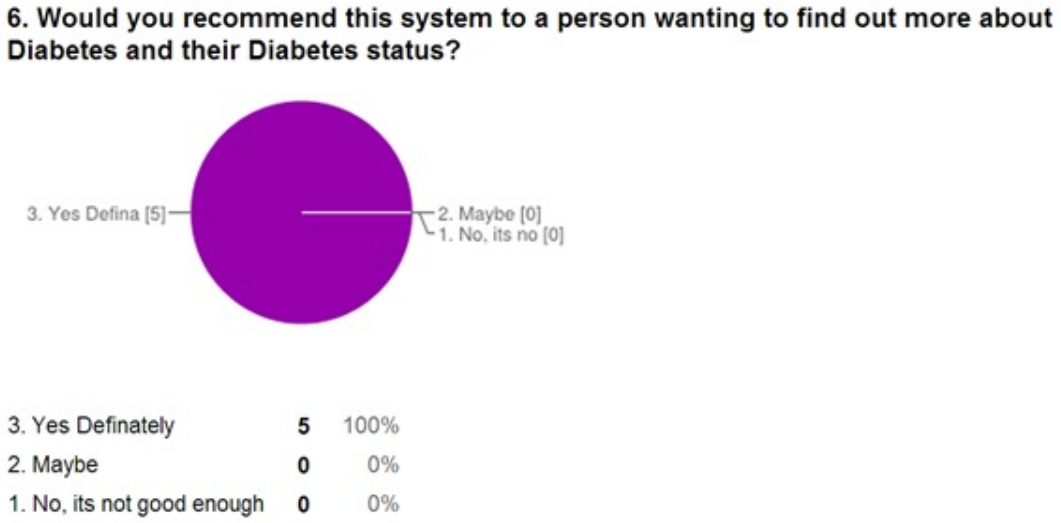

Figure 8.1: Question 6.

8.2 Future Work

There are a lot of changes that could still be implemented to this system. The following are areas that could still be looked into, to further enhance the system:

Animations and illustrations

Animations and illustrations could be utilized to describing certain aspects of Diabetes in more depth. Users had stated that even though the information is comprehensive, the presentation could be made a lot more interactive and fun for the user. Some users even suggest gamifying[1] the information section to make it entertaining.

Text-to-speech

The displayed information could be read out verbally by the system. This could keep the user more engaged with the system, and would reduce the strain on the eyes and mind that is caused by reading a lot of text.

Language translation

Zulu is the most commonly[2] spoken language in South Africa, with about 10% of the population speaking English as their first language. Thus having a system that can reach out to non- english speaking users would increase the penetration capabilities of this and other similar systems. Only the text shown to the user will need to be translated, without the need to alter any programming logic.

Mobile Interface

Developing a mobile interface for this Expert System will increase the accessibility of the system. The current interface has been developed for desktops and laptops. If a mobile interface is created then users can access the system on tablets and mobile phones.

Educational Tool

The framework and approach used in this system implementation could easily be used for an educational tool. By customizing the rule based engine it is possible to conduct dynamic and interactive questionnaires and quizzes. The current percentage calculation can be altered to represent correctly answers questions.

[1] Gamification is the use of game thinking and mechanics in a non gaming environment to engage the users in certain task.

[2] Results from the 2011 Census state that more than a fifth of the population of South Africa speak isiZulu at home, more than any other language

Bibliography

[1] IDF Diabetes Atlas. 5th Edition - http://www.idf.org/diabetesatlas

[2] IDF Diabetes Atlas, Africa. 5th Edition - http://www.idf.org/diabetesatlas/5e/africa

[3] Audrey Mbogho, Joel Dave and Kulani Makhubele. "Diabetes Advisor - A Medical Expert System for Diabetes Management". Fifth International IEEE EAI Conference on e-Infrastructure and e-Services for Developing Countries (AFRICOMM 2013), Blantyre, Malawi, November 25-27, 2013.

[4] Basciftci F, Hatay O. Reduced-rule based expert system by the simplification of logic functions for the diagnosis of diabetes. Computers in Biology and Medicine 41 2011; 350-356.

[5] Diabetes Research and Clinical Practice Volume 94, Issue 3 , Pages 311-321, December 2011.

[6] Abraham, Ajith. "Rule Based Expert Systems." Handbook of measuring system design (2005).

[7] Beynon Davies, P., Mackay, H., and Tudhope, D. (2000). Its lots of bits of paper and ticks and post it notes and things..: a case study of a rapid application development project. Information Systems Journal, 10(3), 195-216.

[8] Ernerst Friedman-Hill. Jess in Action. Rule based systems in Java.

[9] Gediga, Gunther, Kai-Christoph Hamborg, and Ivo Duntsch. "Evaluation of software systems." Encyclopedia of computer science and technology 45.supplement 30 (2002): 127-53.

[10] Jamieson, S. (2004). Likert scales: how to (ab) use them. Medical education, 38(12), 1217-1218.

[11] Opperman,Reinhard , and H. Reiterer. "Software evaluation using the 9241 evaluator." Behaviour and Information Technology 16.4/5 (1997): 232-245.

[12] iang Ming-yan, Chen Zhi-jian-Diabetes Expert System-IEEE International Conference on Intelligent Processing System, 1997.

[13] Introduction to Expert Systems: MYCIN adapted from Harmon, P. D. King. Artificial Intelligence in Business 1985.

[14] Leff, Avraham; James T. Rayfield (September 2001). "Web- Application Development Using the Model/View/Controller Design Pattern". IEEE Enterprise Distributed Object Computing Conference. pp. 118-127.

[15] S.S. Abu-Naser, H. El- Hissi, M. Abu- Rass and N. El- khozondar, 2010. An Expert System for Endocrine Diagnosis and Treatments using JESS. Journal of Artificial Intelligence, 3: 239-251.

[16] Tiwari M, Mishra B. Application of cluster analysis in expert system - A brief survey. 5 2011; 8: 342-346.

[17] V Smitha. An expert system for diabetes diagnosis. 2010 Ritsumeikan Journal of Asia Pacific Studies Volume 32, 2013.

[18] Wild, Sarah, et al. "Global prevalence of diabetes estimates for the year 2000 and projections for 2030." Diabetes care 27.5 (2004): 1047-1053.

[19] Wills K, Teather D, Innoent O. An expert system for the medical diagnosis of brain tumours. Man-Machine Studies 16 1982; 341- 349.

Appendices

Appendix A

Coding snippets

A.1 BMI

```
(defrule bmi
(sectionFact (name Height) (value ?userHeight))
(sectionFact (name Weight) (value ?userWeight))
=>
(bind ?weight ?userWeight)
(bind ?height ?userHeight)
(bind ?bmi (/ ?userWeight (* ?userHeight ?userHeight))) (assert (BMI ?bmi))

(if (> ?bmi 30) then
(assert (weight-classification Obese))
( assert (Feedback (order ?*currentQuestion*) (stage INITIAL) (url "BMI.GIF*")(explanation "Your BMI is above 30 kg/m2, this classifies you as Obese, this is very concerning because Obesity
is a cause of Type 2 Diabetes. You need to urgently try to manage your diet and incorporate some exercise into your daily/weekly routine.*")))
(bind ?*points* (+ ?*points* 20))
else
(if (> ?bmi 25) then
( assert (weight-classification Overweight))
( assert (Feedback (order ?*currentQuestion*)
(stage INITIAL)(url "BMI.GIF*")(explanation "Your BMI is above 25 kg/m2, this classifies you as Overweight, this is slightly concerning if this is mostly body fat and not muscle.*"))
(bind ?*points* (+ ?*points* 10)) else
(if (> ?bmi 18.5) then
(assert (weight-classification OptimalWeight))
( assert (Feedback (order ?*currentQuestion*) (stage INITIAL)(url "BMI.GIF*")(explanation "Your BMI is between the range of 18kg/2 and 25 kg/2, this classifies you as having an Optimal weight,
well done! Keep doing what you are doing :)*"))))
else
(if (> ?bmi 18.5 ) then
(assert (weight-classification Underweight))
(assert (Feedback (order ? *currentQuestion*) (stage INITIAL) (explanation "Your BMI is below, 18 kg/2, you are slightly underweight, a bit more body mass would be great.*"))))))))
```

A.2 Questions

A.2.1 General and Demographic Questions

(Question (section Initial)(type "Name")(text "Hi, I am Doctor Mellitus, a Diabetes Advisor, what is your name?") (answerType "INPUTT") (order 1))

(Question (section Initial)(type "Age")(text "How old are you?") (answerType "INPUTN") (order 2))

(Question (section Initial)(type "Gender")(text "Are you male or female?")(answerType "MALE-FEMALE") (order 3))

(Question (section Initial)(type "Race")(text "What is your race?") (answerType "OPTIONAL")(order 4)(options "Black-White-Asian- Coloured-Other"))

(Question (section Initial)(type "Weight")(text "What is your weight (Kilograms)")(answerType "INPUTND") (order 5))

(Question (section Initial)(type "Height")(text "What is your height (Meters)") (answerType "INPUTND") (order 6))

(Question (section Initial)(type "Diabetes-Knowledge")(text "Do you know about the disease called Diabetes?") (answerType "YES-NO") (order 7))

(Question (section Initial)(type "Diabetic")(text "Are you a Diabetic?") (answerType "OPTIONAL") (order 8)(options "Yes-No- Uncertain"))

(Question (section Initial)(type "Family-History")(text "Do you have relatives who have been diagnosed with Diabetes?")(answerType "OPTIONAL")(options "Yes-No-Uncertain")(order 9))

(Question (section Initial)(type "Family-Type")(text "Is this relative any of the following?")(answerType "OPTIONAL")(options "Parent-Child-Sibling-Grandparent-AuntOrUncle-Other")(order 10))

(Question (section Initial)(type "Pregnant")(text "Are you Pregnant?") (answerType "YES-NO") (order 11))

(Question (section Initial)(type "Info")(text "NB: The following questions aim to assess your knowledge of keywords used in the rest of the assessment.") (answerType "OPTIONAL")(options "OK") (order 12))

(Question (section Initial)(type "Insulin-Knowledge")(text "Do you know what Insulin is?") (answerType "YES-NO") (order 13))

(Question (section Initial)(type "Glucose-Knowledge")(text "Do you know what Glucose is?") (answerType "YES-NO") (order 14))

(Question (section Initial)(type "Gastro-Knowledge")(text "Do you know what Gastroparesis is?") (answerType "YES-NO") (order 15))

A.2.2 Lifestyle Questions

(Question (section Lifestyle)(type "Smoke") (text "Do You smoke cigarettes?") (answerType "YES-NO")(order 16))

(Question (section Lifestyle)(type "Smoke-Frequency")(text "How often do you smoke, please be honest?") (answerType "OPTIONAL") (options "Hardly-Occasionally-Frequently") (order 17))

(Question (section Lifestyle)(type "Alcohol")(text "Do you consume any alcohol?") (answerType "YES-NO")(order 18))

(Question (section Lifestyle)(type "Alcohol-Frequency")(text "Yes some people may say that alcohol is healthy.. but remember, ONLY in moderation! How often do you drink alcohol?") (answerType "OPTIONAL") (options "Hardly-Occasionally-Frequently")(order 19))

(Question (section Lifestyle)(type "Exercise")(text "Do you do any sort of explicit physical exercise?") (answerType "YES-NO")(order 20))

(Question (section Lifestyle)(type "Exercise-Frequency")(text "That's great, How often do you exercise?") (answerType "OPTIONAL") (options "Hardly-Occasionally-Frequently")(order 21))

(Question (section Lifestyle)(type "Blood-Pressure-Knowledge")(text "Have you checked your blood pressure recently?") (answerType "YES- NO")(order 22))

(Question (section Lifestyle)(type "Blood-Pressure")(text "What level is your blood pressure?") (answerType "OPTIONAL")(options "Low- Average-High")(order 23))

A.3 Rules

A.3.1 Smoke

(defrule smokeNo

(declare (salience 10))

(sectionFact (name Smoke) (value ?yesno))

?question <- (Question (section Lifestyle) (type "Smoke- Frequency"))

=>

(if (eq ?yesno No) then

(modify ?question (ask no))

(assert (Feedback (order ?*currentQuestion*) (stage LIFESTYLE) (url "smoke.jpg")(explanation "No smoking you say..? ThatâĂŹs quite commendable, try not to get into this habit as it is quite hard to shake and has a lot of negative effects on the body in the long term.*")))

else

(modify ?question (ask yes))

))

A.4 Symptoms

(deffacts symptomReason

(Reason (name Fatigue)(type SYMPTOM)(points 2)(url "fatigue.jpg") (explanation "Fatigue - The glucose is not being converted into energy this weakens the cells and causes fatigue."))

(Reason (name Frequent-Headache)(type SYMPTOM)(points 4)(url "headache.jpg")(explanation "Frequent Headaches - This is due to the high level of glucose in the blood, this leads to frequent headaches experienced for prolonged periods of time."))

(Reason (name Extreme-Thirst)(type SYMPTOM)(points 10)(url "thirsty.gif")(explanation "Extreme Thirst - Dehydration is caused by excess urine, this prompts an increased desire for water consumption."))

(Reason (name Excessive-Urination)(type SYMPTOM)(points 10)(url "urination.jpg")(explanation "Excessive Urination - There is a high loss of Glucose through the urine."))

(Reason (name Nausea)(type SYMPTOM)(url "nausea.jpg")(points 5) (explanation "Nausea - Nausea is one of the symptoms of gastroparesis."))

(Reason (name Weight loss)(type SYMPTOM)(points 10)(url "weightloss.jpg")(explanation "Weight loss - Insulin deficiency leads to loss of weight, as the sugar cannot be converted into energy, so the body seeks alternative sources like muscle tissue and fat.")) (Reason (name Irritability)(type SYMPTOM)(points 1)(url "irritability.jpg")(explanation "Irritability - Caused by a lack of energy. As the sugar is not being converted into energy to be used by the cells."))

(Reason (name Yeast-Infection)(type SYMPTOM)(points 8)(url "yeast.jpg")(explanation "Yeast Infection - Yeast (a type of fungus) organisms are present in most woman, but these organisms tend to overgrow in a sugar rich environment. A result of badly managed diabetes"))

(Reason (name Blurred-Vision)(type SYMPTOM)(points 3)(url "vision.jpg")(explanation "Blurred Vision - The fluctuation in blood glucose levels leads to a light sensitivity. Also this can be caused by the tissue being pulled from the eye lenses to be used for energy by the body."))

(Reason (name Slow-Healing-Wounds)(type SYMPTOM)(url "wound.jpg") (points 5)(explanation "Slow Healing Wounds - Elevated blood sugar levels cause narrowing of blood vessels, leading to a decreased blood flow and oxygen to the wounds."))

(Reason (name Numbness)(type SYMPTOM)(points 4)(url "numb.jpg") (explanation "Numbness - The nerves in the body get damaged over time, leading to a tingling sensation, pain and eventual loss of sensation"))

(Reason (name Gum-Infection)(type SYMPTOM)(points 8)(url "teethandgum.jpg")(explanation "Gum Infection - High glucose levels in saliva promotes growth of bacteria that cause gum disease.") (extraInfo "Diabetes reduces the bodyâĂŹs resistance to infection, which increases the probability of the gums becoming infected."))

(Reason (name Extreme-Hunger)(type SYMPTOM)(points 8)(url "hunger.jpg")(explanation "Extreme Hunger - The dropping blood sugar levels lead to a desire for more food and energy."))

(Reason (name Erectile-Dysfunction)(type SYMPTOM)(points 10)(url "dysfunction.jpg")(explanation " Erectile Dysfunction - This is a result of the nerve damage in the body."))

(Reason (name Gestational-Diabetes)(type SYMPTOM)(points 10)(url "gestational.jpg")(explanation "Gestational Diabetes - During pregnancy there is a lot of hormonal activity within the body, this affects the functioning of the insulin and might alter/interfere with how the body responds to the insulin. This condition usually subsides after the pregnancy"))

(Reason (name Dry-Mouth)(type SYMPTOM)(url "drymouth.jpg")(points 7)(explanation "Dry Mouth - This is caused by dehydration in the body."))

(Reason (name Abdominal-Pain)(type SYMPTOM)(points 8)(url "abdominal.jpg")(explanation "Abdominal Pain - Because of the gastroparesis, the stomach cannot empty its contents properly leading to stomach pain and cramping"))

A.5 Diabetes Information

(Information (question "7. Diabetes management*")

(explanation "Type 1 Diabetes is difficult to control thus the treatment is a daily task. The strict regimen includes a carefully calculated diet, planned physical activity and multiple insulin injections (frequently). As well as a home blood glucose testing facility to check the levels throughout the day.- Type 2 Diabetes treatment typically includes diet control, frequent exercise, and a home blood glucose testing facility and in certain cases oral medication and insulin injections. The majority of Type 2 Diabetics do not require insulin injections.- Gestational Diabetes is brought about by hormonal effects of the pregnancy, thus no supplementary insulin is required. The patient needs to ensure they exercise appropriately and maintain a healthy diet throughout the pregnancy to avoid developing type 2 Diabetes in the long run.- As a diabetic, your body cannot make proper use of insulin, leading to a high blood glucose level throughout the body. One needs to eat healthy to keep the blood sugar levels within range, this is a very critical aspect of living with Diabetes. A dietician can help cater a diet specific for you as this depends on your BMI(Body Mass Index), medicine, lifestyle and any health problems that one might have. A healthy diabetic should do the following: Limit foods that are high in sugar. Eat small portions spread throughout the day. Watch the carbohydrate intake. Eat a variety of whole grains. Eat less fat . Limit the intake of alcohol. Use less salt.- Exercise is essential for a diabetic, it will not just help with weight loss, but it will also help the body use insulin better, so it can convert glucose into energy for cells. It does not even have to be very strenuous, even just walking regularly will help. Stress should be managed, because stress hormones, may alter blood glucose levels directly. Meditation could be utilized as a very useful tool to manage stress.- Diabetics should take good care of their feet, skin, eyes and teeth and gum. Diabetics have a higher risk of blindness, cataracts and gum problems. So basic dental hygiene like brushing teeth and flossing along with regular dentist visits will help tremendously. Because of the loss of sensation, this could mean not noticing a wound or infection for a prolonged period of time, so it is advised to check your feet regularly.*")

(caption "These are tips on how to manage a life after having being diagnosed with Diabetes. There is unfortunately no proven cure for Diabetes Depending on the type of Diabetes you have been diagnosed with, the treatments differ slightly*") (questionType "MULTIPLE*") (options "Type 1-Type 2-Gestational-Diet-Lifestyle- Body Maintenance*"))

(Information (question "6. Diabetes prevention*") (explanation "Diabetes can be prevented, if the right precautions and mind-set are incorporated into everyday life. There are certain things that are not in oneâĂŹs control, like family history and age. But one can take full control of their weight, lifestyle, habits and diet. Please refer to the response to question 7 for the appropriate measures to prevent the onset of Diabetes. Managing Diabetes is the same as preventing it, as it encourages a healthy diet and lifestyle. *"))

(Information (question "5. Diabetes complications*") (explanation " Diabetes dramatically increases the risk of various cardiovascular problems, including coronary artery disease with chest pain (angina), heart attack, stroke and narrowing of arteries (atherosclerosis). If you have diabetes, you are more likely to have heart disease or stroke.- Diabetes can damage the blood vessels of the retina (diabetic retinopathy), potentially leading to blindness. - The kidneys contain millions of tiny blood vessel clusters that filter waste from your blood. Diabetes can damage this delicate filtering system. Severe damage can lead to kidney failure or irreversible end stage kidney disease, which may require dialysis or a kidney transplant.- Excess sugar can injure the walls of the tiny blood vessels (capillaries) that nourish your nerves, especially in the legs. This can cause tingling, numbness, burning or pain that usually begins at the tips of the toes or fingers and gradually spreads upward. Left untreated, you could lose all sense of feeling in the affected limbs. Damage to the nerves related to digestion can cause problems with nausea, vomiting, diarrhoea or constipation. For men, it may lead to erectile dysfunction.- Nerve damage in the feet or poor blood flow to the feet increases the risk of various foot complications. Left untreated, cuts and blisters can become serious infections. Severe damage might require toe, foot or even leg amputation.- Diabetes may leave you more susceptible to skin problems, including bacterial and fungal infections. With gum infections being a major concern *")

(questionType "MULTIPLE*")

(caption "Diabetes has a lot of complications that can manifest if the disease is not managed appropriately, early diagnosis plays a large role in preventing the complications from arising.*") (options "Cardiovascular Disease-Eye damage-Kidney damage-Nerve damage-Foot damage-Skin and mouth conditions.*"))

(Information (question "4. What are the symptoms of Diabetes*") (explanation "The fluctuation in blood glucose levels leads to a sensitivity to light. Also another reason is a result of the tissue being pulled from the eye lenses to be used for energy by the body.- This is caused by dehydration in the body, the mouth tends to get dry because of the high loss of liquids through urination.- This is a result of the nerve damage in the body, leading to males not being able to perform sexually. A lot of males experience erectile dysfunction- There is a high loss of Glucose through the urine,

this causes one to go to the toilet very often.- The dropping blood sugar levels lead to a desire for more food and energy, causing a continuous feeling of hunger.- Dehydration is caused by excess urine, this prompts an increased desire for water consumption.- The glucose is not being converted into energy this weakens the cells and causes fatigue.- This is due to the high level of glucose( ) in the blood, this leads to frequent headaches experienced for prolonged periods of time.- During pregnancy there is a lot of hormonal activity within the body, this affects the functioning of the insulin and might alter/interfere with how the body responds to the insulin. This condition usually subsides after the pregnancy- High glucose levels in saliva promotes growth of bacteria that cause gum disease, because bacteria thrives in such an environment.- This is caused by a lack of energy. As the sugar is not being converted into energy to be used by the cells, leading to irritability.- Nausea is caused by gastroparesis.- The nerves in the body get damaged over time, leading to a tingling sensation, pain and an eventual loss of sensation.- Elevated blood sugar levels are caused by the gradual narrowing of blood vessels, leading to a decreased blood flow and oxygen to the wounds. This increases the amount of time taken to heal. - Insulin deficiency leads to loss of weight, as the sugar cannot be converted into energy, so the body seeks alternative sources like muscle tissue and fat, gradually eating away at the body.- Yeast organisms are present in most women, but these organisms tend to overgrow in a sugar rich environment. A result of badly managed diabetes. *")

(questionType "MULTIPLE*")

(options "Blurred Vision-Dry Mouth-Erectile Dysfunction- Excessive Urination-Extreme Hunger-Extreme Thirst-Fatigue-Frequent Headaches-Gestational Diabetes-Gum Infection-Irritability-Nausea- Numbness-Slow Healing Wounds-Weight loss-Yeast Infection*")

(caption "Diabetes can be picked up through the symptoms that manifest over time. There are a lot of symptoms that come with Diabetes. Although with Type 2 Diabetes, these signs of Diabetes might not be made visible through symptoms for a very long time, making it difficult for someone to know their Diabetes status*"))

(Information(question "3. What are the different types of Diabetes?*") (explanation "Type 1 Diabetes occurs when the beta cells in the pancreas are damaged. Because of this, the pancreas does not produce insulin anymore. Type 1 normally occurs in people under the age of 30 (it used to be called Juvenile Diabetes).-Type 2 Diabetes occurs when the cells in the body are resistant to the effect of insulin. It develops gradually over a period of time. There is a high association with a family history of Diabetes and obesity. Type 2 normally occurs in people older than 40 years of age-. This type of diabetes affects about 2during last months of pregnancy. Pregnant women have enough insulin, but the effect of insulin is partially blocked by other hormones produced in the placenta during the pregnancy. This causes an abnormal rise in sugar levels in the body. This is a complication of pregnancy and normally disappears after the pregnancy.- Prediabetes, also known as impaired glucose tolerance is the condition where the blood glucose levels in the body are much higher than normal but not high enough to be classified as Diabetes. If the condition is tackled at an early stage through diet, exercise and other healthy lifestyle changes (weight management programme), the risk of going on to develop Type 2 Diabetes can be significantly reduced.*")

(questionType "MULTIPLE*")

(options "Type 1-Type 2-Gestational-Prediabetes*")

(caption "There are two distinct types of Diabetes: Type 1 Diabetes and Type 2 Diabetes. Prediabetes is a condition that may eventually lead to Diabetes. Gestational Diabetes is a condition that occurs in some woman during pregnancy that may (in some cases) eventually lead to Type 2 Diabetes after the pregnancy.*"))

(Information (question "2. What are the risk factors of Diabetes? *") (explanation "Obesity is thought to be a primary cause of Type 2 Diabetes in people who already have a family history of the disease. When a person is obese, the body has to deal with more nutrients than it can handle, to counter this, the cells stop reacting to insulin as long as the body is overweight. This leads to the whole body to eventually be resistant to insulin, the onset of Type 2 Diabetes- If someone in your family had/has Type 2 Diabetes, then you too are at risk of developing the disease. The closer the relative the greater the risk, with studies showing that people with one parent with Diabetes have double the risk, while people with two diabetic parents have six times the risk of being diagnosed with Diabetes, with mothers presenting a greater risk than fathers. Family history is a great contributing factor that people often down play and take for granted.- If the pancreas is damaged and not working properly this leads to insufficient insulin secretion, the onset of Type 1 Diabetes.*")

(questionType "MULTIPLE*")

(options "Obesity-Family History-Pancreas malfunction*") (caption "There are a few risk factors that will vastly increase your chances of developing Diabetes, these are obesity, family history of Diabetes and the malfunctioning of the Pancreas*"))

(Information (question "1. What is Diabetes Mellitus?*") (explanation "Diabetes Mellitus, more commonly known simply as Diabetes is a chronic medical condition where a person has high blood sugar levels. This is either because the insulin production in the body is insufficient or because the body does not respond properly to insulin*"))

(Information (question "0. KEYWORDS*") (explanation "Glucose is the most important simple sugar in a human metabolism, blood glucose is the level of glucose present in the blood stream.- The cardiovascular system consists of the heart, blood vessels and the blood that the blood vessels transport throughout the body. The cardiovascular system is powered by the heart.- Chronic diseases are long lasting diseases that can be controlled but not cured.- Dehydration is an excessive loss of body water.- Erectile relates to the act of having an erect penis during sexual intercourse.- Fatigue is a mental and/or physical state of being tired and weak.- Gastroparesis is a disease of the muscles of the stomach or the nerves controlling the muscles that causes the muscles to stop working, affecting the digestive process.- Gestational relates to the time during a pregnancy.- Insulin is a hormone produced by the Pancreas that is the main regulator of the glucose (sugar) in the blood.- Obesity is a medial condition in which the body has excess fat to the extent that it has negative effects on health (resulting in a shorter life expectancy).- The Pancreas is long soft organ behind

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your stomach and in front of your spine, it produces insulin to help break down the food and hormones that help control the blood sugar levels.- Secretion is the process of releasing a substance.*")
(questionType "MULTIPLE*")
(options "Blood Glucose-Cardiovascular System-Chronic Disease- Dehydration-Erectile-Fatigue-Gastroparesis-Gestational-Insulin- Obesity-Pancreas-Secretion*")
(caption "Important keywords that will be needed to understand definitions*")
)
)
```

A.6 Final assessment function

```
(deffunction assessPercentage()
(bind ?percentage (* (/ ?*points* ?*total*) 100))
(if (> ?percentage 90) then
( assert (Feedback (order ?*currentQuestion*) (stage FINAL) (explanation " You have an extremely high risk of Diabetes!!! This a great concern and should be dealt with immediately you should go to the nearest hospital and seek professional medical attention as soon as possible. Only after blood glucose tests, can you be officially diagnosed with Diabetes*"))) else
(if (> ?percentage 75) then
( assert (Feedback (order ?*currentQuestion*) (stage FINAL) (explanation " You have a very high risk of Diabetes! This should be viewed as a great concern and should be dealt with immediately you should go to the nearest hospital and seek professional medical attention as soon as possible. Only after blood glucose tests, can you be officially diagnosed with Diabetes*"))) else
(if (> ?percentage 50) then
( assert (Feedback (order ?*currentQuestion*) (stage FINAL) (explanation " Your chances of getting diabetes is greater than 50%, this is higher than the average person and should be checked with a medical professional.*"))) else
(if (> ?percentage 40) then
( assert (Feedback (order ?*currentQuestion*) (stage FINAL) (explanation "Your risk of Diabetes is around the 50% region, this should be seen as a concern and should be taken as a warning sign. "))) else
(if ( > ?percentage 30) then
( assert (Feedback (order ?*currentQuestion*) (stage FINAL) (explanation " You have a low risk of Diabetes, it should not be anything to worry about, provided you continue to eat well and live a healthy lifestyle.*"))) else
( assert (Feedback (order ?*currentQuestion*)
(stage FINAL) (explanation "You have a very low risk of Diabetes, this is because of your lack of threatening risk factors, symptoms and your decent lifestyle habits, please do continue and remember to eat healthy and keep active. Diabetes cannot be cured but it can be prevented!*")))))))
(bind ?percentage (* (/ ?*points* ?*total*) 100))
(bind ?number (format nil %3.0f ?percentage))
(bind ?text (str-cat "You have a " (str-cat ?number "% Risk of Diabetes.*")))
( assert (Feedback (order ?*currentQuestion*) (stage FINAL) (explanation ?text))) )
```

Appendix B

Graphs

B.1 Iteration 2

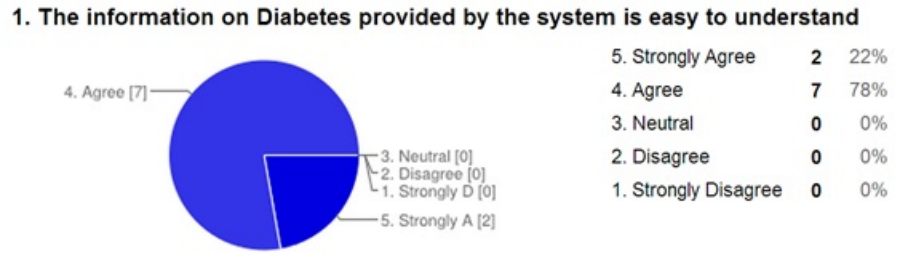


Figure B.1: Question 1.

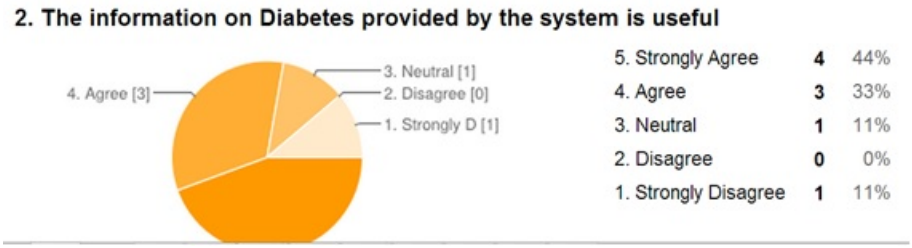
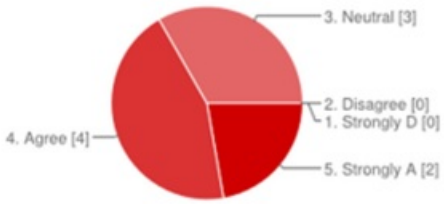


Figure B.2: Question 2.

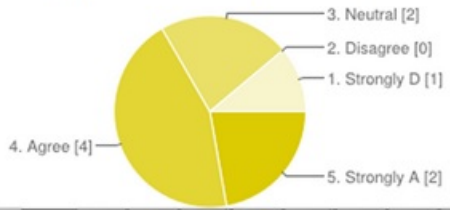
3. The advice provided by the system is correct and useful?



5. Strongly Agree	2	22%
4. Agree	4	44%
3. Neutral	3	33%
2. Disagree	0	0%
1. Strongly Disagree	0	0%

Figure B.3: Question 3.

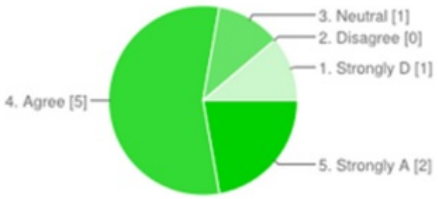
4. The symptom feedback provided by the expert system is easy to understand?



5. Strongly Agree	2	22%
4. Agree	4	44%
3. Neutral	2	22%
2. Disagree	0	0%
1. Strongly Disagree	1	11%

Figure B.4: Question 4.

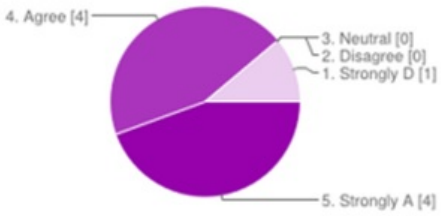
5. The symptom feedback provided by the expert system is useful?



5. Strongly Agree	2	22%
4. Agree	5	56%
3. Neutral	1	11%
2. Disagree	0	0%
1. Strongly Disagree	1	11%

Figure B.5: Question 5.

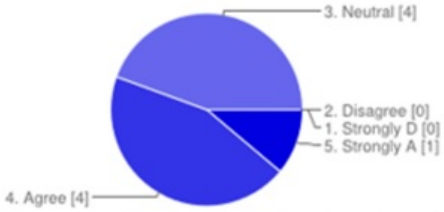
6. The questions asked by the system are relevant.?



5. Strongly Agree	4	44%
4. Agree	4	44%
3. Neutral	0	0%
2. Disagree	0	0%
1. Strongly Disagree	1	11%

Figure B.6: Question 6.

7. This assessment considers all the possibilities that a Doctor would during an interview with a patient?



5. Strongly Agree	1	11%
4. Agree	4	44%
3. Neutral	4	44%
2. Disagree	0	0%
1. Strongly Disagree	0	0%

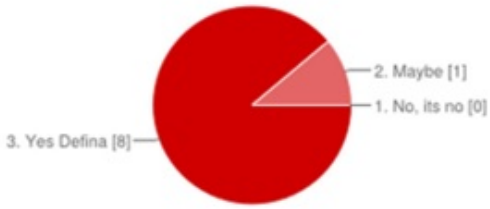
Figure B.7: Question 7.

9. Would you recommend this system to a person wanting to find out more about Diabetes and their Diabetes status?

3. Yes Definately	8	89%
2. Maybe	0	0%
1. No, its not good enough	1	11%

Figure B.8: Question 9.

10. This Expert System has the potential to raise Diabetes awareness in South Africa?



3. Yes Definately	8	89%
2. Maybe	1	11%
1. No, its not good enough	0	0%

Figure B.9: Question 10.

Figure B.10: Question 12.

B.2 Iteration 3

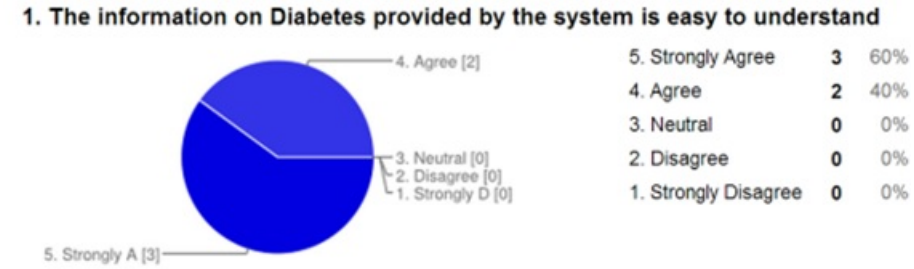


Figure B.11: Question 1.

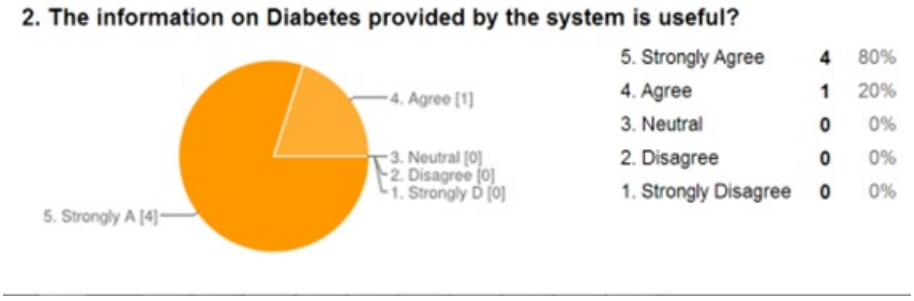


Figure B.12: Question 2.

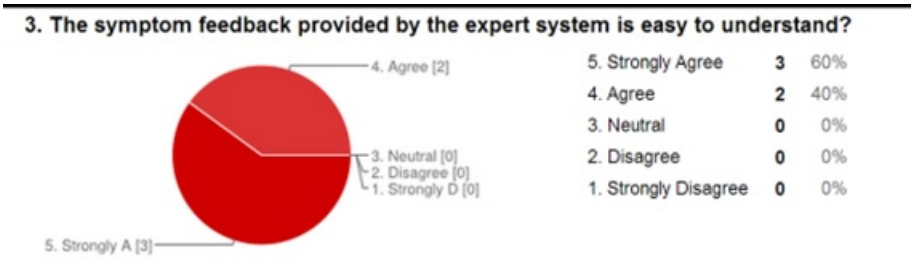


Figure B.13: Question 3.

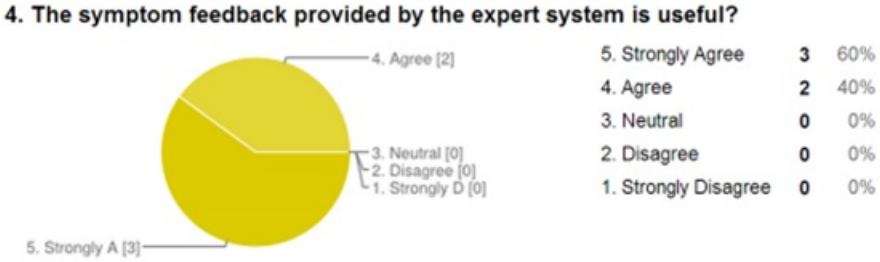


Figure B.14: Question 4.

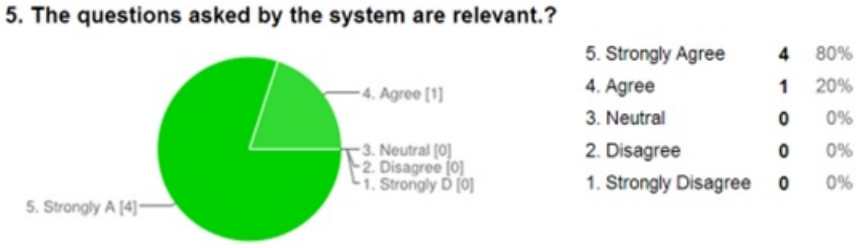
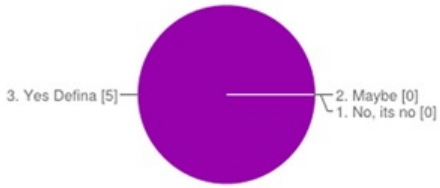


Figure B.15: Question 5.

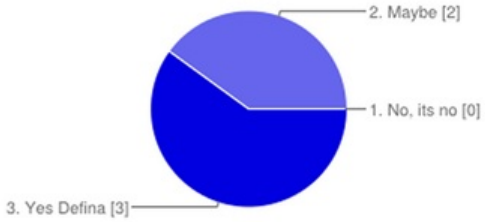
6. Would you recommend this system to a person wanting to find out more about Diabetes and their Diabetes status?



3. Yes Definately	**5**	100%
2. Maybe	**0**	0%
1. No, its not good enough	**0**	0%

Figure B.16: Question 6.

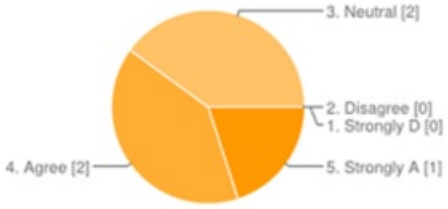
7. This Expert System has the potential to raise Diabetes awareness in South Africa?



3. Yes Definitely	**3**	60%
2. Maybe	**2**	40%
1. No, its not good enough	**0**	0%

Figure B.17: Question 7.

8.A person with basic computer skills can use this system.?



5. Strongly Agree	**1**	20%
4. Agree	**2**	40%
3. Neutral	**2**	40%
2. Disagree	**0**	0%
1. Strongly Disagree	**0**	0%

Figure B.18: Question 8.

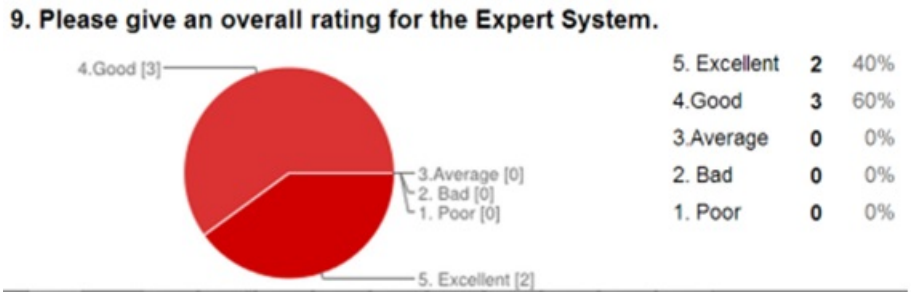


Figure B.19: Question 9.

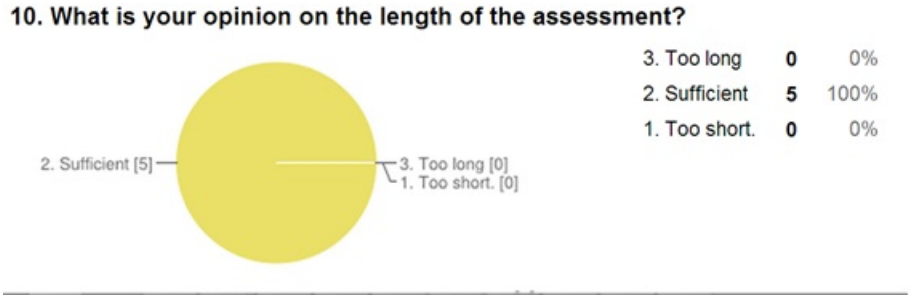


Figure B.20: Question 10.

B.3 Images

Figure B.21: Default Image.