Honours Project Report

Human Interaction Design for knowledge based expert system

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

Abstract

Keywords: diabetes, human-computer interaction, expert systems

Acknowledgements

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List of Abbreviations

1. INTRODUCTION

1.1. Definition of the Problem

Expert systems require an exhaustive knowledge base and a functional user-friendly interface in order to be effective [7], the latter however, is often not given enough attention [7, 8]. In this paper, information visualisations on a web based graphical user interface are applied instead of simplified texted-based interfaces for Expert systems which have been found to be deficient [7].

Many factors such as the thinking process of an individual influence the design of a user interface [5]. An expert system should cater for different human mental models as one individual may feel the system is effective and another may feel otherwise. Explanations should be clear and concise whilst maintaining a usable interface. Problems encountered in expert system user interfaces are due to designing the interface using user requirements rather than user's thinking process as well as HCI lacking in some of the most widely used development methodologies such as the Agile method [8].

An interface for a Diabetes Advisor Expert system in particular will be the focus of this paper as it has to cater for patients that may be illiterate mentally or functionally. To ensure that the user interface adheres to the conventional guidelines, HCI heuristics are applied to the interface and thorough user testing is incorporated throughout the design process in order to cater for the various mental models and thinking processes of users.

1.2. Motivation and Aim

In rural areas, overcrowding in medical clinics has been a major issue due to the lack of resources in terms of medical staff and facilities. The use of an expert system reduces the workload on the medical staff. The diabetes advisor expert system may assist the medical staff whenever a patient may be in need of information on diabetes as well as assessing their chances of becoming diabetic.

The majority of medical expert systems such as MYCIN, make use of text-based user interfaces and require the user to undergo prolonged assessments which may take up to thirty minutes to complete.

The aim of this project is to design an intuitive and easy to understand web-based expert system which is accessible on multiple devices such as laptops and Smartphones and gives advice to users concerning diabetes. The interface should accommodate various mental models and thinking processes through the use of visual representations of entities.

The system should be fluid and dynamic to allow for quick retrieval of information from the user as well as an instantly responsive user interface which facilitates uninterrupted navigation.

1.3. Structure of report

This report is broken into a number of chapters

- **Background Chapter**

This chapter goes into detail regarding HCI, Expert Systems and web-based expert systems. The literature of Human Computer Interaction is reviewed and how it relates to expert systems. This chapter also discusses related work on web-based and standalone expert system which have been implemented.

- **Requirements Analysis and Design**
  This chapter discusses the process of gathering what features and content is required on the Diabetes Advisor expert system from medical experts and users who'll be interacting with the system.

- **System Development and Implementation**
  This chapter explains in detail how the system is implemented taking into consideration the technologies used to design the interface and how the interface is integrated to the knowledge base of the expert system.

- **Evaluations and Results**
  This chapter discusses the testing and evaluation techniques used to test usability of the system. The success of the system is also discussed based on the evaluation.

- **Conclusion and Future work**
  This chapter will summarize everything that has been done and the revelation obtained through the course of the project. Future work on web-based expert systems will also be elaborated.

2. Background

2.1. Human Computer Interaction

The use of technology has grown rapidly over the years and the manner in which humans interact with computers is continuously changing as a result. What was considered the norm ten years ago, such as using a mouse for navigation, is now considered archaic due to the adoption of touch-based navigation. Furthermore, devices such as Smartphones now play a large role in the lives of their users and it is important that the interaction between the user and smartphone is simple and straightforward. The interface of the device the user is interacting with should cater not only for expert user but also the average user, especially the computer illiterate users in developing worlds. In order to facilitate effective interaction between a human and the interface being communicated with, careful consideration of human processing involved in interacting with computer systems is required and HCI assists in achieving that goal.

Human computer Interaction (HCI) studies the interactions and the relationships between humans and computers, hence facilitates design which is user-friendly when accomplishing tasks using a Computer [23]. HCI is essentially as a set of processes, dialogues, and actions through which a user employs and interacts with a computer. HCI can be defined as a discipline concerned with the design, evaluation and implementation of interactive computer systems for human use with the study of major phenomena surrounding them

[16]. The use of pull down menus, visual metaphor such as a trash can icon to symbolize the discarding of files or a folder icon to symbolize an object which stores files are a means of communication between human and computers.

According to [23], HCI has focused on interfaces, particularly on the possibilities and design criteria for graphical user interfaces using windows, icons, menus, and pointing devices, to create more usable systems. However it has since gone beyond focusing on interfaces and has taken on new essential challenges which involve improving the way people use computers to work, communicate, learn, argue, calculate, design and more [23].

2.1.1. Foundation of Human Computer Interaction

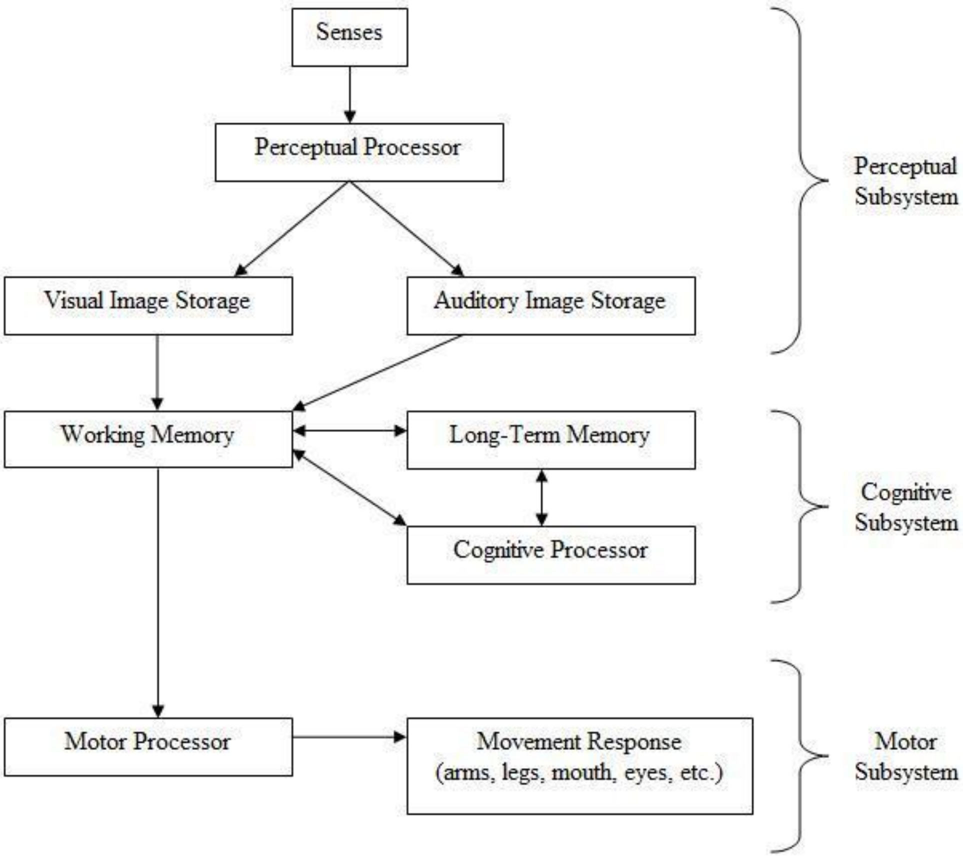
The fundamental components of an interactive system as HCI entails include the human user, the computer and the interaction that takes place between a user and a computer. The human component deals with psychological and physiological attributes of the user as well as the capabilities and limitations that may affect the user's ability to use computer systems. In HCI, understanding of a user at this level is necessary in order to classify what makes a design successful.

The computer component considers the capabilities and limitations of a computer system and how users may interact with it. The design of input and output devices control the manner in which interaction is performed and taking into consideration the existing designs of computer hardware, interfaces need to be well-suited for the hardware at hand.

The interaction component involves different models of interaction which are applied to interfaces for effective and logical dialogs between a user and a machine.

The Human

As stated in [15], Card, Moran and Newell [17] described the Model Human Processor. The MHP is a simplified view of the human processing involved in interacting with computer systems. MHP comprises three subsystems namely the perceptual system, the motor system and the cognitive system. Each subsystem has a processor and storage memory [15].



The input and output channels, such as vision, hearing, touch and movement, facilitate information flow between a human and a computer. At least one channel is utilized by a human during reasoning, problem solving and acquisitioning of skills. Humans differ in terms of the proficiency of the capabilities they have. During information processing, the given information is stored in the human's memory which is why it is important to reduce the cognitive loads of users when designing an interface as one user may have a greater memory capacity than another [15,16].

In addition, though input in a human can come through various senses, the most commonly used senses are vision, hearing, touch, taste and smell. HCI mainly focuses on vision, hearing and touch as they are the human senses which are central in designing computer systems [15].

In this thesis, the expert system designed only requires two senses ideally, vision and touch.

- **Vision**

  User interfaces are largely dependent on the visual information they produce hence, vision is arguably the most important input channel [16]. Light is an electromagnetic radiation which is responsible for vision. Light is received by the human eye and based on the objects reflected by light; the eye is able to transform the illuminated objects into electrical signals which are then passed to the brain to form an image.

Visual perception can be divided into two stages: the physical reception of the stimulus from the outside world, and the processing and interpretation of that stimulus. Visual perception involves the ability of the eye to perceive size and depth, brightness and colour [16].
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- Size and Depth
- Brightness
- Colour

- **Touch**

  Touch, which is also referred to a haptic perception, deals with the physical interaction between a human and computer. Applying pressure on a device in order to activate certain events of action, mechanoreceptors respond, allow the user know that they have pressed an object on the interface without the need of auditory feedback to notify the user.

The Computer

Interaction with a computer generally involves the transfer of information, whether it may be information (events fired by the user) informing the operating system to perform a certain task or a user communicates with another. For information transfer to take place, two components are used, namely input devices and output display devices.

- **Input devices**

  Input is transferred through any device, such as a keyboard, mouse, touch-enabled screen, handwriting recognition processor and speech recognition embedded microphone, which is capable of receiving input from the user and transferring the data received to the computer system at hand. Users are expected to use the input devices to communicate their intentions in a manner which is interpretable by the computer.

  The system implemented in this thesis is designed to interact with a user using a keyboard, touch-enabled screen and mouse [15, 16].

- **Output display devices**

  Output devices display the feedback produced by the computer in a human-readable manner. However, output being human-readable does not mean the user can interpret the information. Unlike computer systems, humans do not share capabilities in motor skills or mental skills. Therefore, output is managed in various ways in order to meet the needs of users [16]:
  *

  - Graphical user interfaces (GUI) and multi-window systems have become common-place.

- Output devices that can fit in laptop and pocket computer (e.g. Ipad) are become com-monplace.
- Vision, moving pictures, sound and, touch are being combined in hypermedia system.
- Various forms of three dimensional (3D) outputs are also available for specific purposes.
- The use of both speech and non-speech audio output has become more common, with facilities for synthesized speech and sampled sound now standard on many machines.
- Specialized forms of output that stimulate sense of touch are available. Those are for use in specific market, or aimed at people with particular disabilities.

Output devices play a significant role in facilitating communication between a human and computer. Output devices may be used without the input of a specific user, for example, screens displaying the schedule for flights are do not require input from those viewing it for information. However, input devices require output in order to inform the user that information is being transferred.

The Interaction

According to [18], the term “User Interface” refers to the methods and devices that are used to accommodate interaction between machines and human beings, users, who use them. The sole purpose of an interface is communicating information from the product to the user, and communicating from the user to the product. The term “Graphical User Interface” is used to describe a user interface which consists of graphical elements. The term is used to refer specifically to user interfaces which have graphical elements due to the fact that the first interactive user interfaces on computers were not graphical [18].

The evolution of user interfaces is mainly made possible through the advancement in hardware technology. As shown in the table below, user interfaces have evolved several times, dating from programming, batch processing user interface paradigms to WIMP (windows, icons, menus, and pointing device) user interface paradigm which is used today.

Generation	Hardware technology	Operating mode	Programming languages	Terminal technology	User types	Advertising image	User interface paradigm
-1945 Pre-history	Mechanical, electro-mechanical (Babbage, Zuse Z3)	Calculations	Plugboard, jumpers, cable	Lights	Inventors	-	-
1945-1955 Pioneer	Vacuum tubes, huge machines, short mean time between failures	One User at a time at machine	Machine language	Punch Cards, typewriter, TTY	Experts, pioneers	Calculator	Programming, batch processing
1955-1965 Historical	Transistors	Batch System	Assembler	Line-oriented terminals	Technocrats, professional computerists	Information processor	Command languages
1965-1980 Traditional	Integrated circuits (IC)	Time-sharing	High-level languages	Full-screen terminals, alpha-numeric characters only	Normal Users with special knowledges	Enhance Productivity	Full-screen hierarchical menus and form fill-in
1980-Now	VLSI, Wafer-scaled integrations	Network, single user and embedded systems	Problem oriented languages	Graphical Displays, Desktops, Laptops, embedded systems, cellulars, ...	Everybody	Computer for everybody (without knowledge)	WIMP (Windows, Icons, Menus, Pointing Device)

Table 1 - Summary of the generations of computers and user interfaces [18]

The next generation of user interfaces are being put into practice at the moment. Hardware technology is currently advancing towards wearable hardware such as the Oculus Rift virtual reality headset for 3D gaming and Google glass, a wearable computer with an optical head-mounted display. Interacting with such technology will require sound and speech input as support for keyboards and the mouse would be unsuited.

In terms of the various styles of interaction which have been used in the past and which are currently been used, interaction design has seen significant improvements. Earlier computer interfaces were command-driven and comprised of form-fill applications where necessary. Such interfaces were mainly used by expert users and knowledgeable people whom are willing to take the time to acquire the skills required to establish communication with the computer [16].

Form-fill applications applied metaphors in design which resembled forms in the real world. Clerical users who had little experience with computers would be able to perform repetitive clerical data collection tasks through the aid of a form-fill interface [16].

The styles mentioned above are still relevant amongst certain users and are still in use, however other interaction styles, namely menus and direct manipulation, have been introduce in over time. These interaction styles are usually combined in order provide a complete and intuitive way of interacting with a computer system. ~

2.1.2. User Interface Design in HCI

User Interface design in HCI involves the creation of well design interfaces for products and systems through understanding the needs of the end user and being able to interpret human users and implement their psychological, physical and cultural characteristics in the design process. This requires careful planning, research and visualisation skills [18].

There are design considerations in HCI which need to be fulfilled in order to meet the standard of what end users are accustomed to. The Eight Golden Rules of interface Design and Nielsens Heuristics to interface design both presents underlying principles of interface design that are applicable in most interactive systems [15].

These principles of interface design are listed below:

- **Eight Golden rules**

  1. **Strive for consistency**
     The interface should be consistent throughout, all the fonts should match and the color, capitalization; layout and so on should be consistent. As stated in [19] Consistent sequences of actions should be required in similar situations, identical terminology should be used in prompts, menus, and help screens, and consistent commands should be employed throughout.

  2. **Enable frequent users to use shortcuts**
     Expert and frequent users may desire to reduce the number of interactions they have to perform and instead speed up the pace of interaction by means of shortcut keys, abbreviations, hidden commands and macro facilities [19]. Short response times and swift display rates are also important in reducing the time spent interacting with a system.

  3. **Offer informative feedback**
     For every operator action, the system should provide the user with constant feedback. For frequent and minor actions, the response can be modest, whereas for infrequent and major actions, the response should be more substantial [18, 19].

  4. **Design dialog to yield closure**
     The user needs to know that they have reached a milestone during their sequences of actions. Dialog that yield closure give the operator a sense of accomplishment, a sense of relief, the signal to drop contingency plans and options from their minds, and an

indication that the way is clear to prepare for the next group of actions.

5. **Offer simple error handling**
   The system should be designed so that it is able to avoid user input causing a serious error. For example, if a user inputs a number instead of a word the system should not allow the user to do so, thus avoiding potential errors.

6. **Permit easy reversal of actions**
   Actions that may potentially be made by mistake or indecisively by a user should be reversible. This feature allows the user freedom to explore the system knowing that every action they make can be undone.

7. **Support internal locus of control**
   Users want to feel that they full control of the system; hence the system needs to respond to their actions as opposed to the user responding to the systems instead.

8. **Reduce short-term memory load**
   The human short-term memory is limited. The interface should be minimalistic and fewer words should be used.

   Additionally, when organizing the display design, using these rules (Shneiderman, 1987, p.80) provides the experience that is more effective [18].
   · Consistency of data-entry transactions; delimiters, abbreviations, etc
   · Minimal input actions by user
   · Minimal memory load on user
   · Compatibility of data entry with data display
   · Flexibility for user control of data entry

❖ **Nielsens Heuristics** (only the principles not already included in the 8 golden rules are listed)

9. **Match between system and the real world**
   The system should accommodate the user by speaking the users' language, using concepts familiar with the users or using metaphors or idioms in the user interface, rather than system-oriented terms.

   Real-world conventions should be followed in order to make the information appear in a natural and logical manner [20].

10. **Aesthetic and minimalist design**

Minimalistic design encourages the exclusion of dialogues which are irrelevant and rarely needed. This assists in reducing the short-term memory load of a user.

11. **Help and Documentation**
    Help and documentation, even though the system can be used without, it may be helpful to users who are less explorative and prefer knowing how the system operates beforehand.

The heuristically-centred design principles have been discussed; however there are concepts of graphical user interface design underlined and derived heuristically from experience, which should also be considered and applied in the design process.

- Learnability vs. Usability
- Metaphors and Idioms
- Intuitiveness
- Consistency
- Simplicity
- Prevention
- Forgiveness
- Aesthetics

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The design considerations allow the designer to plan their design process effectively keeping in mind all the guidelines that need to be conformed to. The process of design for user centred design includes five steps: Requirements gathering, analysis, design, iteration and prototyping, implementation and deployment [15].

1. **Requirements**
   Through observations and interviews, the features of the system to be designed are mapped
2. **Analysis**
   Through various methods, the gathered requirements are ordered to bring out key issues
3. **Design**
   Various design guidelines help in moving from what is needed to how to do it. These guidelines are discussed in the design chapter.
4. **Iteration and prototyping**
   Real users are tested and feedback given after these tests are used to further improve the system
5. **Implementation and deployment**
   This step is performed concurrently with the iteration and prototyping step. The features gathered from iteration and prototyping are implemented.

Using the user centred design approach; the user's characteristics and needs are effectively captured through their involvement. During the requirement step, the user is involved in the design process from the very beginning, and the iteration and prototyping step will require the user's input on possible improvements and additional feedback on whether the requirements from the previous iteration have been met. The design heuristics discussed above also from part of the user centred design as well as usability testing which will be discussed in the evaluation chapter.

2.2. Expert Systems

Expert systems are a branch of artificial intelligence and thus use domain specific knowledge in order to explain, resolve and conclude a problem from the defined domain [2, 9]. Expert systems gather knowledge from human experts and attempt to use the acquired knowledge to solve real world problems relating to the human experts domain [2]. Expert systems use the stored knowledge to make a decision and use rationing of an expert to give a specialized response.

There are four features that classify a program as an expert system: proficiency level is that of an expert, uses an inference mechanism to reach a conclusion, the knowledge in the knowledge based is capture from the expertise of a human, storing of data in a database acquired from the knowledge of an expert in a specific domain.

2.2.1. Architecture of Expert System

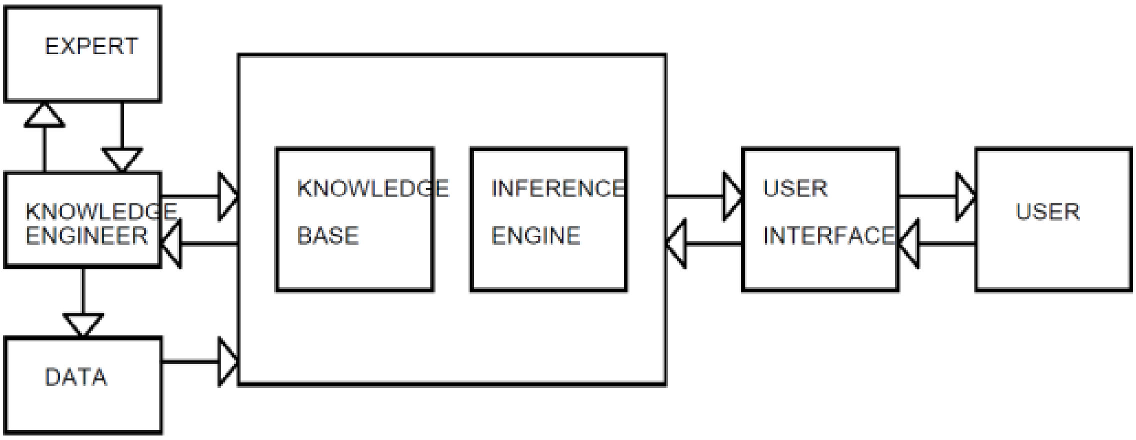

Figure 1- Basic structure of a knowledge based expert system [9]

The main modules of an expert system are [2]:

- **Knowledge base**
  Permanently stores the system's knowledge that has been gathered from an expert in a respective domain [2]. The knowledge is represented in the form of production rules [7] and facts which are organized in a way that facilitates inference [2]. In the case of a diabetes advisor expert system, the knowledge base can be divided into two parts [11]:
  - **Static knowledge base**
    It consists of rules that do not change when the system is modified.
  - **Dynamic database**

It holds data which is created during run time relating to specific patient cases being tackled by the system at the time. The data is then removed once the system is done executing [11].

An example of a rule that guides dosage combination:
IF (patient is on regimen 4)
AND (regimen long acting insulin is great)
THEN (the dosage is of unusual proportions for the day)

The format of the rules is in the following form: IF <conditions> AND <conditions> THEN <action list> ELSE <action list>

- **User Interface**
  It facilitates bi-directional communication between a user and the expert system [9]. It consists of questions in the form of text or speech [7]. Imagery and visual aids may also be used to communicate with the user. Input is provided by the user for each question the system presents and then the system outputs the appropriate dialog in response to the user's input.

- **Working memory**
  It can also be referred to as a dynamic database, due to its function in temporarily storing data and facts during program execution [12].

- **Inference Engine**
  Its responsible for the reasoning of an expert system as it uses the knowledge currently stored in the system to solve a problem by selecting rules to be applied using forward or backward chaining [7].

2.2.2. Expert Systems Interfaces

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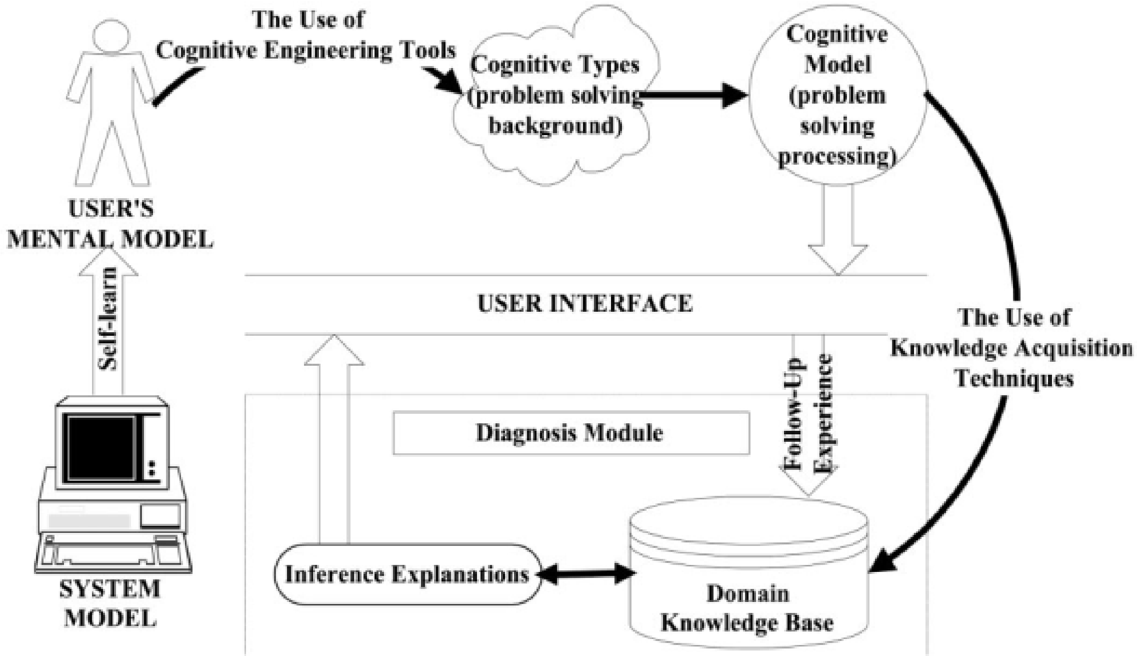

Figure 2 – Expert system interface developed model

The user interface collects facts entered by a user and saves the collected data into the fact base [12]. Furthermore, the interface can be used by knowledge engineers to gather knowledge which is required through a knowledge acquisition interface [12]. Two types of interface will be discussed: Web-based graphical user interface and speech-based user interface.

Graphical user interface

The web-based interface graphically represents the explanations of the process at hand and conclusions reached using output produced by the expert system in text form or visual graphics [12].

When designing an interface, the general issue that needs to be addressed is how to effectively establish a natural dialog between the user and the artificial intelligence, while at the same time, computationally efficient [7]. Furthermore, when the expert system is web-based, the response time becomes a critical factor in maintaining a natural and consistent dialog [9]. To achieve desirable performance from a web based expert system, a minimalistic yet useful interface is required to cut down on bandwidth setbacks whilst providing information using lightweight design principles. A good interface or dialog also assist in the decision making process about tasks and task performance [9].

There are various technologies that are used to manage dialog based on context, and in this paper the following technologies will be discussed: Natural Language Processing, context-based reasoning and dialog system design [7].

a. Natural Language Processing (NLP)

In developing countries, especially in rural areas, literacy levels are low. NLP facilitates Human computer interactions (HCI) using the users' native language [7]. This allows for either a text-based interface for users who may be computer literate or speech-based interface for users who are not computer literate.

b. Context-based reasoning (CxBR)

   Context-based reasoning can be used to further enhance Natural Language Processing by providing resolution of semantic ambiguity through contextualisation techniques [7]. This technology however introduces issues ranging from speech recognition errors and limited dialogs between the users and the artificial intelligence [7]. Context can constrain a domain without being involved in that particular domain explicitly [13]. The main idea for context based reasoning is to allow for the adapting of solutions used to solve previous problems and use them to solve new problems [14].

c. Dialog system design

   Dialog system design can be used to further enhance Natural Language Processing by providing conversational dialogs which are more natural and dynamic [7].

The use of effective dialog design can improve the user interface of an expert system to a certain extent; however it does not cater for users who severe human limitations such as deafness or being mute. Some deaf people do not understand any form of native text-based languages and rely entirely on sign language as a form of communication. Thus, the use of metaphors should also be incorporated to the user interface on a medical expert system.

Metaphorical reasoning is another factor which is usually overlooked when dealing with user interfaces. Users of a system are more likely to make sense of something they're not familiar with by making comparison with what they know about something similar [9]. This gives rise to an opportunity to design an interface which is entirely based on imagery and visual aids to enable users to interact with the expert system using their intuition and metaphorical reasoning.

Finding a balance between dialog and visual interactivity can result in a user interface that can adapt to the user's preference by making explicit assumptions about the user and responding differently where necessarily [9].

2.3. Web-Based Expert Systems

The convergence of technologies in the internet and the field of expert systems offer ways of sharing and distributing knowledge through various internet technologies [21]. Earlier applications of expert systems were standalone, based on mainframe, AI workstations or PC platforms then later came LAN-based distributed applications [21]. The In [21], Power [22] argues that rapid advances in internet technologies have opened new opportunities for enhancing traditional decision support systems and expert systems. Several web-based expert systems such as WITS and the fish-expert exist today and benefit from the superior distribution benefits that the internet provides.

Benefits and Challenges of Web-based Expert Systems

In [21], the benefits and challenges are examined from different perspectives, namely technological, methodological, economic, and social.
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- **Knowledge Acquisition**
  The impact of the Internet on knowledge acquisition can be profound. Firstly, it provides another valuable knowledge source. Secondly, it makes knowledge elicitation from the domain expert possible at a distance. Thirdly, as Basden [3] argued, the users can be closely involved in the selection and generation of the knowledge. However, these benefits bring with them problems and challenges including dealing with information overload, effective knowledge mining techniques, locating and verifying online experts, filtering knowledge, managing conflict when several online experts are involved, and security and reliability consideration.

- **Knowledge Representation and inferencing**
  Traditional development methodologies, tools, and techniques that work effectively in a standalone environment may not work well in a web situation.

- **Knowledge Validation**
  The knowledge validation, verification, and testing process is likely to be one of the most useful additions due to ES development. Users can directly submit their test cases or provide feedback to system developers via the Internet. Alternatively, the knowledge base can be uploaded for validation and be accessed directly by users. However, this approach needs a centrally managed validation process. Generic online debugging tools would be welcomed by developers.

- **Explanation and justification**
  One of the distinguishing features of an ES is its ability to explain and justify results. This function is enhanced by using Internet technology. It is also possible to receive explanation and justification from a human expert via the Internet. Therefore, future web-based ES shells could have built-in functions to facilitate online real time communications.

- **System evaluation, Implementation and maintenance**
  From the users' point of view, systems can be easily accessed globally; their location is irrelevant and no installation is needed at the users' location. Any updating and maintenance can be carried out centrally. Users' feedback can be collected via online feedback forms for later analysis. Web-site analysis tools can be installed to trace the number of visitors and their behaviour; this is not normally possible with traditional ES. As the system can be operated at the site

of the originators who are responsible for it, its maintenance, upgrading, and monitoring can be more effective and efficient.

- **Web-based ES development tools**
  Traditional ES were developed for standalone computers. However, many shells do not support the openness and interoperability required for deploying ES over a wide area network [24]. Unfortunately, the web was originally conceived as a document distribution infrastructure and any attempt to use it for distributing expert systems must cope with difficulties. Some web-based ES tools are commercially available, but no formal evaluation and comparison of different ones has been conducted.

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2.4. Related Work

- **MYCIN**
  MYCIN was the first well known expert system developed by Shortliffe at Standford University to assist doctors in prescribing antimicrobial drugs for blood infections. The creators of MYCIN however did not take into consideration the requirements of the users and designed a terminal-driven interface which was not user friendly to doctors [239]. Furthermore, MYCIN took up to 30 minutes of the users’ time in order to complete the assessment.

  The system designed in this paper aims to reduce the time needed to complete the assessment by a considerable amount compared to MYCIN as well as design a user-interface which is appealing to the average user as well as the experts which it will assist.

- **Easy Diagnosis**
  Easy diagnose provides a list and clinical descriptions of the most likely conditions based on an analysis of the symptoms experienced by the user or patient. The user-interface is poorly designed and requires the user to answer a considerable number of questions without receiving any feedback of their data being recorded for diagnoses.

  The system designed in this paper takes into consideration the issue of not giving constant feedback to the user.

2.5. Summary

3. Requirements Analysis and Design

3.1. System Overview and Requirements

The aim of this project is to build a web-based Diabetes Advisory Expert System. This system is interactive and processes information dynamically in order to keep the interaction between the user and the system as fluid as possible. User input is continuously processed in the background by a rule based engine that decides the flow of the questions and the conclusions to reach based on the processed information. There are three components which are required in order to build the initial prototype and make it functional namely the graphical user interface, the rule-based engine and the intermediate.

- **The Graphical User Interface**
  The user interface shall serve as means of communication between the user and the system.

- **The Controller**
  This intermediary component will serve as the mechanism used to integrate the interface to the rule-based engine, allowing for information flow to occur between the user and the system.

- **The Rule Based Engine**
  The rule-based engine will store the rules needed to reach a conclusion based on the data given through the interface.

3.2. Methodology and Phases of Design Process

A user-centred approach was used to in order to gather the initial requirement regarding the features the interface should comprise of. The system was developed using an iterative and incremental approach, which included users throughout the design process. Evolutionary prototyping was used in the design process and refinement took place iteratively.

A typical design process diagram can be seen in figure 3.

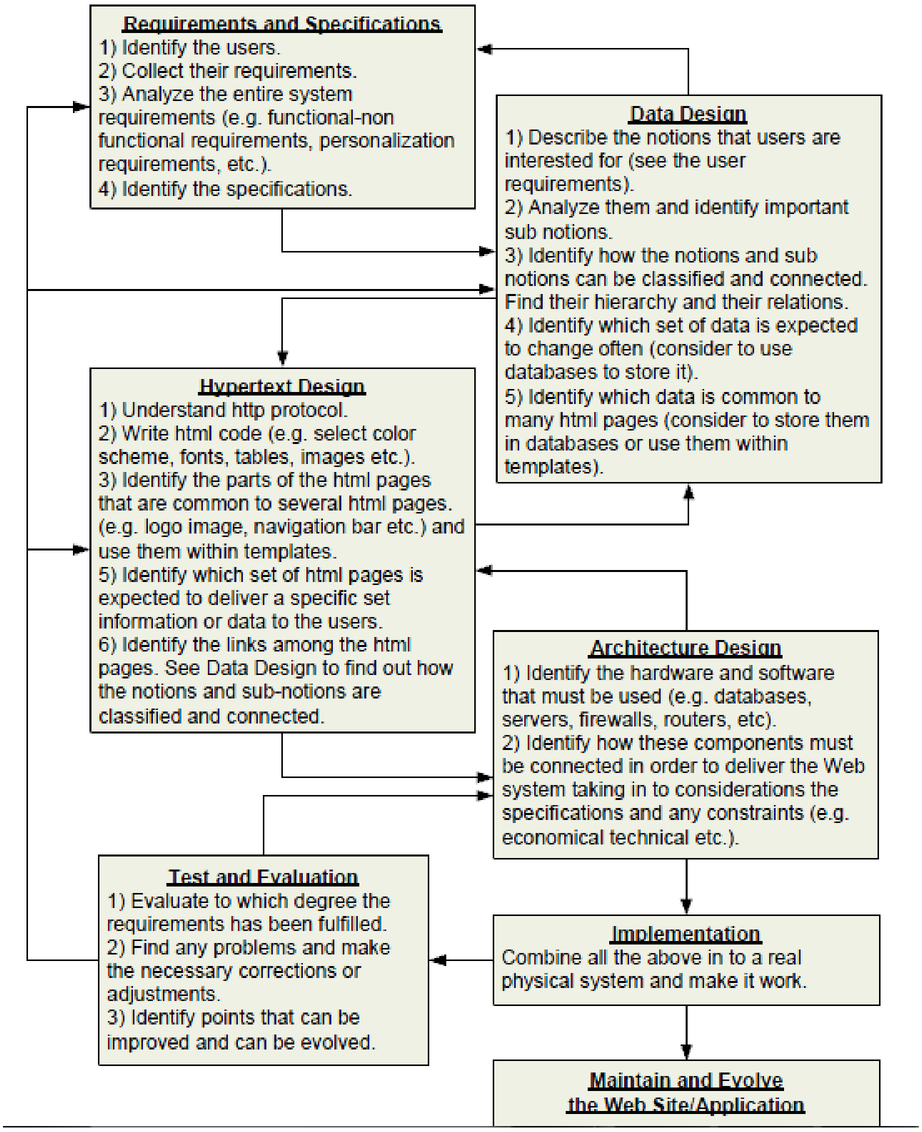


Figure 3 - Web Site/Applicatoin Developing Process [26]

3.2.1. Initial Prototype

❖ **<u>Requirements gathering</u>**

To gather initial system functional requirements, a participatory session was done with a medical doctor. Medical doctors use a certain approach when dealing with diabetic patients and the objective for the first requirements gathering was to ensure that the system adhered to those procedures. The user should be able to communicate with the diabetes advisor expert system as they would a human medical doctor.

❖ **<u>Results and findings for initial prototype</u>**

The medical doctor mentioned features which would make the interface more user-centred and the procedures used in diabetes assessments

The features are as follows:

- ❖ Include the users name

- Options to select the avatar of the diabetes advisor
- Cater for people with blurry vision
- Extra information when hovering on objects on the interface
- Allow users to select multiple symptoms
- The interface should be easy to understand and clean
- Graphical representation of symptoms
- Symptoms should be grouped according to gender
- Show users what could happen if treatment is not received
- Show the nearest clinic where treatment can be administered
- System should give advice rather than diagnosing.

- **<u>Initial Prototype Design</u>**

Based on the interface features suggested in the initial phase of the requirements gathering, an evolutionary robust prototype was made. The initial screen can be seen below. Refer to Appendix A for viewing the other screens included in the prototype. The figure 3 below is the initial screen where the user enters their name. On the top right corner, the avatar of the diabetes advisor is placed.

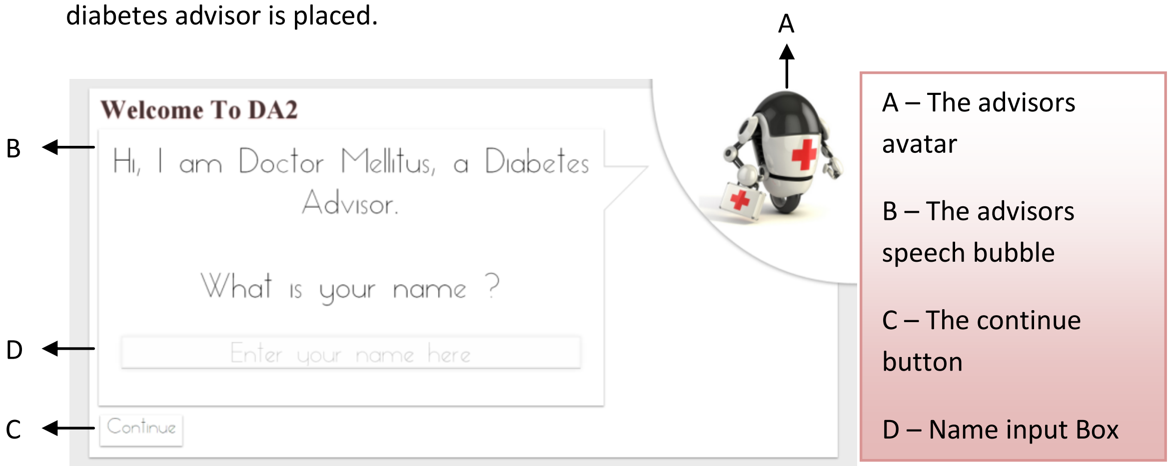
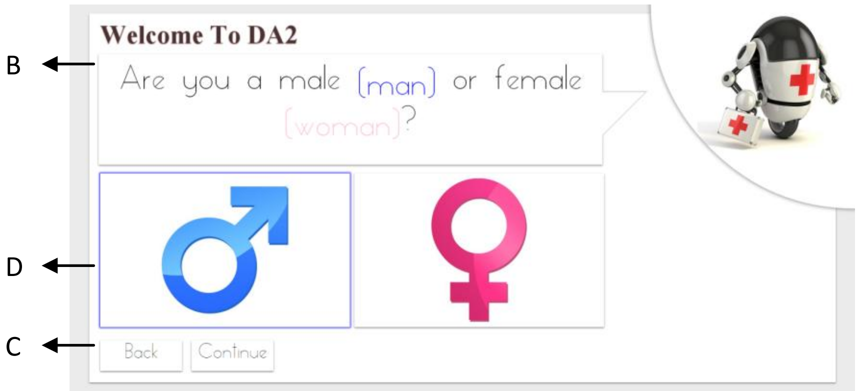


Figure 4 - The initial prototype's initial screen

A

The initial screen consists of the input text box for the user's name. The entered name will be user throughout the system to refer to the user on a more personal level. Once the name is entered, continue is clicked in order to move on to the next screen. Alternatively, if the user does not wish to enter their name, clicking the continue button will skip this screen altogether and the system will proceed with the assessment without knowing the name of the user.



A – The advisors avatar

B – The advisors speech bubble

C – The back button

D – The patients section with options

Figure 5 – Second Screen of the initial prototype

Figure 4 shows the second screen in which the user has two options to select from, either male or female. Depending on which option is selected, the symptoms will be filtered according to gender. For example, the erectile dysfunction symptom should not be selectable by a female user, and the vaginal itchiness symptom should not be selectable by a male user. The remaining screens follow the same conventions up until the symptoms screen. The back button appears in this screen. Pressing the back button in this screen will take the user back to the first screen, and the back button will become hidden again.

Figure 5 shows the third screen in which the user is asked whether he or she is diabetic or not.

Figure 6 shows the dashboard screen in which a user would choose which assessment they would wish to complete. The options include symptoms, risk factors and lifestyle. At this stage in development, only the symptoms option was functional.

In figure 7, the nearest clinic button is clicked, and the nearest clinics are displayed. Clicking the nearest clinic button again will remove the maps.

In Figure 8, explanation of words which the user may not understand are displayed when the user right click on the mouse or alternatively clicks on the more information button ‘ ’

Figure 9 shows the symptoms screen where the users select multiple symptoms which they are experiencing. The symptoms screen is the last screen available in the initial prototype and the assessment did not proceed any further.

3.2.2. First Iteration

- **Requirement gathering**

Now that the evolutionary prototype was prepared using the specifications from a professional medical doctor, the first iteration was conducted with eight non-Computer Science students to find out whether the interface was satisfactory. Users were given the chance to interact with the interface and give any additional requirements they fact where lacking in the interface.

- **Results and findings for the first iteration**

  From the initial prototype the following concerns were raised by the users.

  - Feedback

    The system should provide more feedback to the user whenever input is given. The feedback given should provide an overview of the information currently being processed as well as feedback of the results which are generated from the given information.

  - More information implementation not intuitive

    The system used right clicking on the mouse as a means to show the definition of complicated words. This approach is not intuitive as it requires the user to right click again in order to remove the explanation and return to the normal flow of information.

  - Scrolling in symptoms panel not obvious

    The scroll bar is not easily noticeable, and the user is not given the impression that there are more symptoms to select from. The users suggested that the scroll bar should be more apparent, alternatively a message can be used to inform the user that there are more symptoms to choose from.

  - Submit button did not stand out

    The submit button looked identical to the symptoms buttons and carried no weight. The users suggested that the submit button should have color to separate it from the rest of the buttons.

  - The system lacked color

    Users suggested that more color should be added to the interface to make it more attractive.

  - Was not obvious that the symptoms buttons are clickable

    The system did not inform the users that the symptom buttons required their input. This gave users the impression that the buttons implied that if you had all those symptoms, then the chance for the user being diabetic is high

  - System needed a bolder font

The font was too thin, and users suggested a bolder font which is easier to read and less strenuous to the eyes

- **Prototype after first iteration**

3.2.3. Second Iteration

- **Requirement gathering**

  The second iteration involved users who are medical students. This iteration was mainly for validating the content of the system however a considerable feedback on the interface was given. The approach followed was a participatory design approach as the students interacted with the interface in groups.

- **Results and findings for the second iteration**
  - More Diagrams

    The users suggested using diagrams to further aid in understanding the information given by the system.

  - More pictures

    Pictures illustrating each question should be used. The users suggested that when asked whether a person smokes, an accompanying picture should be used.

  - Interface buttons too large

    The buttons are large and take up too space. The users suggested the button sizes to be reduced in order to make space for pictures

  - Introduction to diabetes at the start of assessment

    There should be an introduction to diabetes dialog in story form explaining what diabetes is.

  - Each section should have unique color palette

    ~

  - Clicking continue button to proceed is tedious

    Users suggested that the system should proceed to the next question upon clicking answering a question without the need to click the continue button,

- **Prototype after Second iteration**

3.2.4. Third Iteration

- **Requirement gathering**

The third and final iteration consists of two separate PD workshops, one with medical students and another with non-computer science students.

- **<u>Results and findings for the third iteration</u>**
  - <u>Percentage bar</u>
    The percentage bar should alert the user when change occurs
    A breakdown of the causes for the increase should also be implemented

  - <u>Voice over for questions</u>
    Questions should be read out loud for the user to hear.

  - <u>The pictures are small</u>
    The pictures of symptoms are small and could benefit from a zoom in feature

- **<u>Prototype after third iteration</u>**

4. System Design and Implementation

4.1. Methodology

Rapid Application Development (RAD) was used in the design and implementation process. RAD puts more emphasis on design and implementation than planning, thus software is written much faster and requirement changes are easier to accommodate. This methodology integrates well with participatory design and user-centred HCI approaches. The process features of RAD further illustrate why this methodology was chosen.

According to [24] process features of RAD include:

- **Focus on deliverables**
  The focus in RAD is more on the deliverables of the development process rather than planning. A particular emphasis is on core functionality and avoiding overly engineered solutions for the problem at hand.

- **Time boxing**
  Project control in RAD involves scoping the project through prioritizing development and using negotiated delivery deadlines. This allows development teams to quickly build the core of the system and implement refinements in subsequent releases [25]. If the projects begin to slip, the emphasis in RAD projects is on reducing the requirements to fit the allocation time, not extending the deadline.

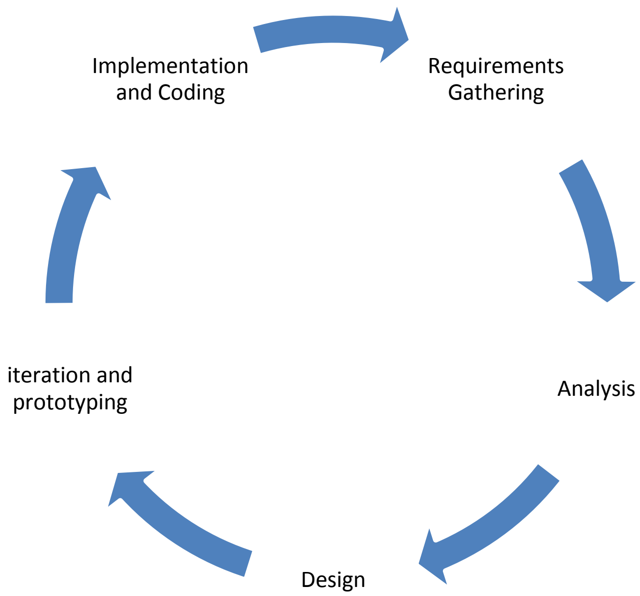
- **Incremental (Evolutionary) Prototyping**
  RAD emphasizes using evolutionary prototypes that are eventually transformed into the final product [25]. The cycle of inspection-discussion-amendment is usually repeated at least three times in RAD projects until the user is satisfied with the system. Prototyping is used throughout the development life cycle.

- **User involvement**
  Active user involvement throughout RAD lifecycle ensures that business requirements and user expectations are clearly understood [25].

- **Developer involvement**
  Ideally, developers should focus only on the RAD project.

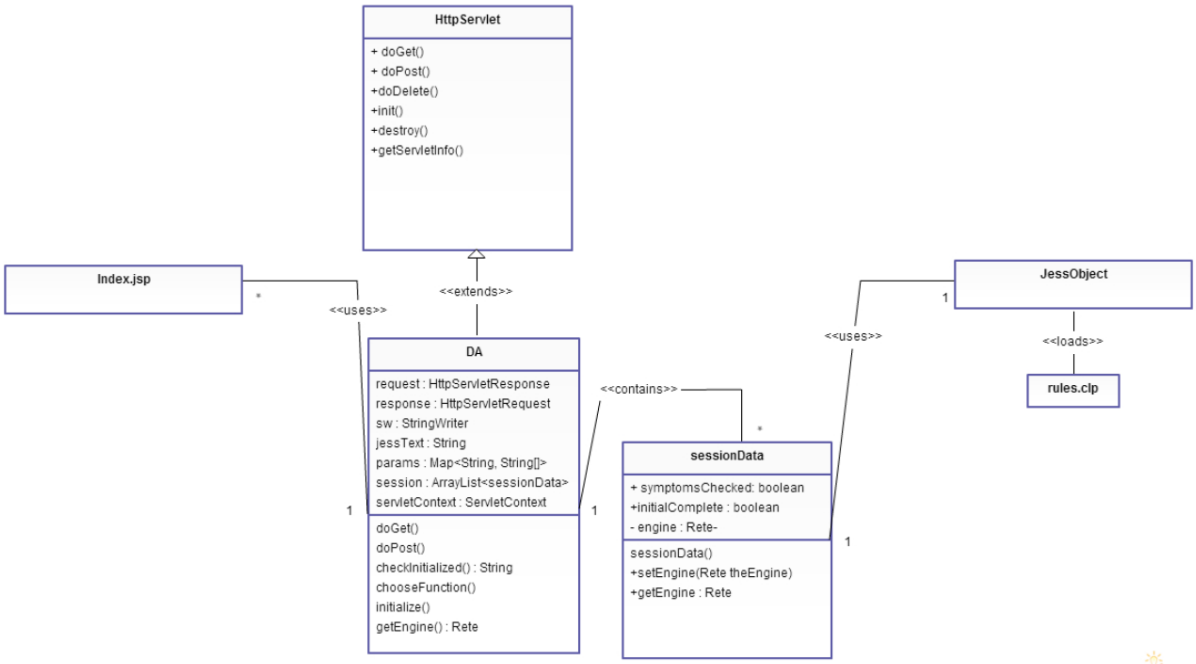
- **User-developer interaction**
  Interaction between the developers and users occurs on a regular, could be daily, weekly or monthly till the completion of the project. Interaction may be organized formally or informally.

The structure of the RAD lifecycle is thus designed to ensure that developers build systems users are completely satisfied with.



4.2. System Architecture

As mentioned in section 3.1. the system has three components. The graphical user interface is implemented in the Index.html file, the intermediary controller is implemented in the DA.java class and the rule-based engine is implemented in the rules.clp file. In order to allow for separate sessions when using the system, a sessionData.java file is used.



The system comprises of the following files:

- Index.html/index.jsp

  The graphical user interface layout is defined in this file. Only one .html/.jsp file was used, instead of multiple .html/.jsp files each containing separate sections of the assessment. The reason for using one file is to avoid page reloading whenever a new page is opened. All the elements required by the system's graphical user interface are only loaded once, and are dynamically made available or unavailable in real-time during interaction. Some elements are loaded from the client-side code directly into the index file using javascript.

- DA.java

  This servlet is used to transfer data between the interface and the rule-based engine. This servlet is shared through all the concurrent instantiations of the web application and in order to avoid users sharing the same session, different session objects, each with sessionIDs used for referencing, are created and stored in an arrayList in the DA.java object.

- sessionData.java

  This file includes the object needed for session tracking. When multiple users are interacting with the system simultaneously, managing different sessions is required. The object included in this file keeps data specific to a unique user's session and their session is changed accordingly whenever the user makes a request.

- rules.clp

  This file contains the rules, logic and facts required by the rule-based engine. This is file is loaded from memory whenever a new JessObject is created. The JessObject is an object of the Rete class which is the central class in the jess library. The JessObject is used to embed JESS in java applications and each object will consist of a working memory, agenda, rules, etc.

4.3. Interface Design

4.3.1. HTML

The Hypertext Mark Language (HTML) is a universally understood language needed to publish online documents. The reason HTML is used instead of Flash or embedded Java applications is its SEO friendly. Search Engine Optimisation allows search engines to easily pick up the Meta data of the web application and list it accordingly whenever a user searches for a diabetes advisor. Such is not possible when using flash and embedded java applications.

HTML tags are used to define the structure of the document (<html></html>). An HTML document is divided into a head section (<head></head>) and a body (<body></body>). The title of the document appears within the head (<title></title>) along with other information about the document such as references to stylesheet and scripts. The content of the document appears within the body tags.

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01//EN"
     "http://www.w3.org/TR/html4/strict.dtd">
<HTML>
   <HEAD>
      <TITLE>My first HTML document</TITLE>
   </HEAD>
   <BODY>
      <P>Hello world!
   </BODY>
</HTML>
```

This example above will simply display the content within the body tags, in the case a paragraph denoted by p tags (<p></p>) will be display 'Hello world!' in the browser.

The tags used for the structure of the interface in index.html are as follows:

- <div>
- <span>
- <img>
- <h1>/<h2>/<h3>
- <p>
- <link>
- <script>
- <title>

~

4.3.2. CSS

CSS stands for Cascading Style Sheets. In the style.css file, the look and feel of the index.html file is defined. The styling specifications can either be contained within

<style> tags anywhere inside the html tags or can be contained in an external file, which is then linked to the html document using the <link> tag.

4.3.3. Javascript

Javascript is used for client-side scripting. JavaScript code can be executed by all modern web browsers and is usually inserted in html by means of script tags (<script></script>) anywhere within the html tags. Alternatively, javascript can be contained in a separate file and referenced in within the head tags.

4.3.4. JQuery

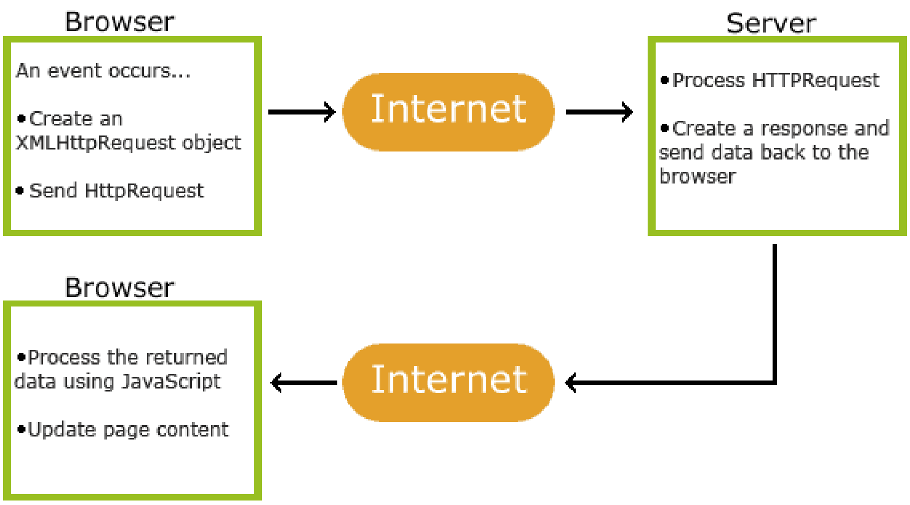
JQuery is a Javascript library which is used to add effects, animations and look-and-feel manipulation to the system. The reason JQuery is used instead of other frameworks such as bootstrap is due to JQuery's popularity and its extendibility.

4.4. The Controller

4.4.1. AJAX

AJAX stands for Asynchronous JavaScript and XML. AJAX is a technique for creating fast and dynamic web pages. AJAX allows web pages to be updated asynchronously by exchanging small amounts of data with the server behind the scenes. This means that it is possible to update parts of a web page, without reloading the whole page.*

If ever the system consisted of multiple html pages without ajax, each entire page should be reloaded if content should change.



4.4.2. JSON

JSON stands for Javascript Object Notation. JSOn is syntax for storing and exchanging text information much like XML. JSON is smaller than XML, and faster and easier to parse. For AJAX applications, JSON is faster and easier than XML.

4.5. The Expert System

4.5.1. Java Servlets

The java servlets contains the Rete object which is used to link to the rules.

4.5.2. JESS

JESS stands for Java Expert System Shell, and is used as the Rule-based Engine in the system. This framework is used instead of CLIPS because it can be easily integrated with Java.

4.5.3. Apache's Tomcat server and Ant

The server of choice to facilitate java servlet, server-side scripting is Apache Tomcat. The building tool used to compile the java servlet for use by the Tomcat server is Apache Ant.

4.6. Interface Integration to Expert System

4.6.1. The Merging Process

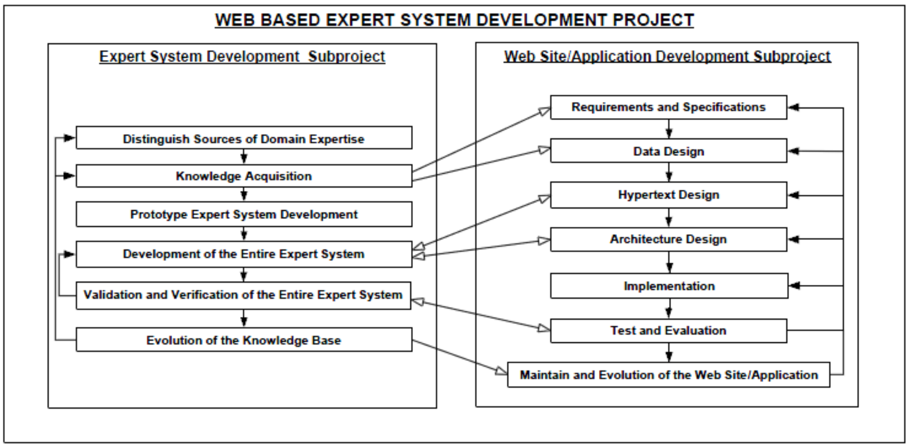


Figure 6 - The merging process [26]

Integrating the user interface to the expert system requires a highly collaborative effort between the knowledge engineer and the user interface designer. The expert system component of the system needs to cater for the user interface component of the system and vice versa.

For example, during the knowledge acquisition process with knowledgeable medical experts, questions asked to the domain experts directly affect the user interface. If the domain experts suggest that the system should provide information which comprises of diagrams, the user interface should be able to cater to those requires which are content specific rather than design specific.

4.6.2. Information flow between user interface and expert system

The most significant piece of code that facilitates the information flow between the user interface and the expert system can be seen in figure 7 below.

```
$.get('DA', { command: "init" }, function (responseText) {
    setSession(responseText);
    ajaxCall("question", responseText);
});
```

Figure 7 - The get method which communicates with the server side code

This is a JQuery, AJAX call which sends in a command to the server and which the server uses in order to figure out which snippet of code to execute. If the executed snippet has output, that output is returned to the front-end using the snippet below.

```
if (params.containsKey("command")) {
    if (request.getParameter("command").equals("question")) {
        question((request.getParameter("sessionID")));
    } else
        if (request.getParameter("command").equals("init"))
        {
            initialize();
```

Figure 8 - The code snippet that checks the command sent to the server from the client

The method which is executed when the command is “init” can be seen in the figure below.

```
public void initialize()
    throws ServletException, IOException, JessException {
    System.out.println("CAALLING ME");
    String session = "";
    if (
        //getServletContext().getInitParameter("first").equals("false"))
        !firstSession)
    {
        session = checkInitialized();
    } else{
        session = "engine0";
        firstSession=true;
        //getServletContext().setInitParameter("first", "true");
    }
    response.setContentType("text/plain");
    response.setCharacterEncoding("UTF-8");
    response.getWriter().write(session);
}
```

Figure 9 - The snippet which is called in the server when the snippet in figure 7 is called in the client

This method returns the session engine to the client using the *response.getWriter().write(session);* The session variable is then returned in the function parameter, responsetext, in the client-side code.

This approach is used throughout the assessment to send and get data to and fro the client and server.

5. Evaluation and Results

5.1. System Evaluation

Three iterations were performed on the evolutionary prototype which was initially built using the requirements and specifications given by a medical expert. Design heuristics and principles mentioned in section 2.1.2.

5.1.1. Heuristic evaluation

❖ **Eight Golden rules**

1. **Strive for consistency**
   Does the design have a convention which is applied across the whole design? Are the various sections and screens in the interface consistent with one another?

2. **Enable frequent users to use shortcuts**
   Does the interface provide shortcuts and accelerators for expert users?

3. **Offer informative feedback**
   Does the user interface give feedback to every operator action?

4. **Design dialog to yield closure**
   Are sequences of actions organized into groups with a beginning, middle, and end?

5. **Offer simple error handling**
   Does the user interface prevent errors from occurring by controlling user input?

6. **Permit easy reversal of actions**
   Does the user interface offer the user a way to reverse their actions?

7. **Support internal locus of control**
   Are the initiators of actions in full control of the system?

8. **Reduce short-term memory load**
   Is the user interface's display kept simple? Are irrelevant phrase and sentences avoided?

- **Nielsens Heuristics** (only the principles not already included in the 8 golden rules are listed)

  12. **Match between system and the real world**
  Does the user interface follow a real world convention that makes information appear in a natural and logical manner whilst using words and phrases that are familiar to the users?

  13. **Aesthetic and minimalist design**
  Does the user interface avoid irrelevant dialogues? Is the user interface clean and appealing?

  14. **Help and Documentation**
  Does the user interface provide a help screen where the user can find out how the system works?

5.1.2. Heuristic evaluation Findings

- **Eight Golden rules**

  1. **Strive for consistency**
  The user interface is consistent throughout the assessment. The upper panel represents the advisor whereas the bottom panel is the patient. Whenever the advisor responds to the user, the reply to the advisor is selected at the bottom panel throughout the assessment. Buttons which the users interact with are also located just below the patient panel, sometimes within it but always below the options given to the user as a patient.

     The feedback design is also consistent throughout with the advisor's panel expanding to reveal feedback in paragraphs.

  2. **Enable frequent users to use shortcuts**
  The user interface enables frequent users to use the enter key to proceed with questions, directional keys to choose between the option on the left or the option on the right and numbers '1,2,3,4,5' to select an option when there's more than two options.

     In the completion screen the user has a shortcut option to restart the whole assessment, open the questionnaire or go to the diabetes information screen.

  3. **Offer informative feedback**
  Informative feedback is given by the user interface whenever a user selects an option. It presents all the information is has currently stored for processing.

The user interface also uses tooltips in order to give extra information on elements which are hovered over.

Whenever changes occur, for example the percentage of the user's chance of being diabetic, a pop up along with a sound, informs that a change has occurred.

4. **Design dialog to yield closure**
   After each section, closure is given by means of feedback, after each feedback dialog, a new section begins, thus sequences of actions are organized into groups with a beginning, middle and end.

5. **Offer simple error handling**
   The user interface prevents the user from entering letters and other characters where such is not permitted. For example, a message notifies the user that only numbers are permitted in the age textbox. Unless the user inputs digits in to this textbox, they may not be able to proceed and no input is recorded.

6. **Permit easy reversal of actions**
   There is a back button located in all screens which permits the user to reverse their actions.

7. **Support internal locus of control**
   Due to the nature of the system, the user isn't fully in control of the system as the system needs to guide the user in order to complete the assessment.

8. **Reduce short-term memory load**
   The user interface is very simple and straight forward. Everything presented to the user is relevant and clear. The assessment generally requires minimal usage of memory.

- **Nielsens Heuristics** (only the principles not already included in the 8 golden rules are listed)

9. **Match between system and the real world**
   The system uses real life conventions such as speech bubbles to show the advisor's interaction with the user. Colors are used the conventional way, with green signalling a low risk, and red signalling a high risk of diabetes.

10. **Aesthetic and minimalist design**
    Pictures and colourful wallpapers are used to make the user interface appealing. The design is minimalist and does not contain too much information at a glance.

11. **Help and Documentation**

Help on how to use the system and what each element means is documented for the user to utilize if ever they need to know how the system works (high level details).

5.2. User Evaluation

Three official user testing sessions were conducted during the development of the web-based expert system. The system being developed is meant to be used by non-experts in computer interaction. Thus, user testing is very important in order to ensure that the system meets the needs of the users. The diabetes advisory expert system is meant to be used by the medical staff that may not be knowledgeable with diabetes and patients who are not are not familiar with interacting with graphical user interfaces.

Unfortunately, due to time constraints, only one potential user of the system in the real world was able to give feedback, our personal medical doctor. Patients can be evaluated in a Masters level project which spans throughout the year.

The system was already integrated during the first user test session, thus both the user interface and the expert system were tested concurrently. The user testing for the expert system is expanded upon in the Knowledge-based component of this project, done by Benjiman Mmary.

5.2.1. Methodology

To test whether the user interface is usable and intuitive, various approaches were used to gather qualitative results from the users' interaction with the system. An informal, intimate approach was taken in order to fully understand how the users feel about the system. The approach involved getting to know the users, talking about more than just the system, which allowed them to relax and not feel under pressure. This gave the users more incentive to assist and hence gave feedback which was *thoroughly thought through.*

The notable methods applied in the user testing sessions are: A Questionnaire, The think aloud method, observation and recording and the constructive interaction method.

- **Questionnaire**
  Three questionnaires were filled during the development of the system. These questionnaires were constructed using Google forms and were carefully designed to collect useful information from the users pertaining to the user interface and the expert system.

- **Think Aloud Method**
  According to Jakob Nielsen [27], in a thinking aloud test, you ask test participants to use the system while continuously thinking out loud, that is, "simply" verbalizing their thoughts as they move through the user interface.

This method is very useful if conducted properly. First of all, getting to know the users before the test and giving them a brief background of the system and what it aims to accomplish is important. This makes the users comfortable and eager to use the system and feel less pressured when being tested. Furthermore, the think aloud method facilitates the observation of users and the manner in which they use the system and what they expect the system to do.

❖ **Constructive Interaction Method**

During the second iteration in particular, the users being tested each brought a laptop of their own as requested. This led to some users working together during the test due to some laptops not being able to connect to the wireless network at the time. The conversations during the users' collaborative interaction with the user interface could be observed and recorded, and much insight was gained in the process.

5.2.2. Testing

❖ **First Iteration**

In the first iteration, 7 users where tested. The initial, evolutionary prototype discussed in section 3.1 was used to gather the users' opinion on the user interface.

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 provdes 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?

Results

Multiple choice

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

				Agree		
6	Entering information, Reading the instructions and questions, Navigating the system, Understanding the system	Reading the instructions and questions, Navigating the system	None of the above	Reading the instructions and questions	Reading the instructions and questions, Navigating the system	Navigating the system

Open Ended

Question 7: Do you find this system useful, why?

Three users replied to this question, they said the following:

- User 3
  "It's useful for people that have no idea about the disease and are worried are about their current health"
- User 4
  "Yes I did, because I learned more about diabetes in two minutes than I had in twenty years! Lol"
- User 5
  "Yes it is. The lack of skills/expertise may be detrimental to some people that need assistance. The system is useful as it will give information while other doctors are occupied in assisting someone else"

Question 8: Any suggestion on how the Expert System can be improved?

Two users answered this question, they said the following:

- User 4
  "More instructions on the symptoms page."
- User 5
  "Maybe give more instructions on how to full out the questionnaire." (Diabetes assessment)

Discussion

This iteration gave significant insight as to what the users required of the system. Furthermore, the questionnaire alone did not capture all the requirements and the other methods used such as the think aloud method and observing their interaction with the system gave even more insight. The requirements not captured by the questionnaire are discussed in section 3.2. along with the changes made to the user interface after each iteration.

The questionnaire in the first iteration was meant to cater for the web-based expert system as a whole, whereas from the second iteration onwards, the questionnaire is divided into user interface questions and expert system questions. This is due to the architecture of the system before and after the first iteration. Initially the system had a low level of modularity between the user interface and the expert system, thus it was difficult to split the work properly as all the information was hard coded in the front-end.

❖ **Second Iteration**

No.	Question
1	The characters on the computer screen are easy to read?
2	Organization of information on screen is clear?
3	Sequence of screens is clear?
4	Position of messages on screen is consistent?
5	Messages on screen which prompt user for input are clear?
6	Computer keeps you informed about what it is doing?
7	Learning to operate the system is easy?
8	Tasks can be performed in a straight-forward manner?
9	Help messages on the screen are helpful?
10	System speed is fast enough?
11	Experienced and inexperienced users' needs are taken into consideration?
12	Use of colors is effective?
13	Any additional comments concerning the user interface?

High modularity had been achieved in time for the second iteration. The user interface and the expert knowledge had become separate yet integrated components thus the questionnaire was split into two parts. At this point, the evolutionary prototype was fully functional and deployable; however various images and diagrams were still missing. Nine 5th year medical students were testing, in a participatory design set up in a conference room.

Results

Multiple Choice

Question No.	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9
1	Agree	Agree	Strong Agree	Agree	Agree	Strongly Agree	Agree	Agree	Agree
2	Agree	Agree	Strongly Agree	Agree	Agree	Neutral	Neutral	Agree	Agree
3	Agree	Agree	Strongly Agree	Strongly Agree	Strongly Agree	Neutral	Neutral	Agree	Strongly Agree
4	Disagree	Neutral	Agree	Agree	Agree	Agree	Agree	Agree	Agree
5	Agree	Neutral	Agree	Agree	Agree	Agree	Agree	Agree	Agree
6	Neutral	Neutral	Agree	Strongly Agree	Neutral	Agree	Strongly Agree	Agree	Strongly Agree
7	Agree	Agree	Agree	Strongly Agree	Agree	Neutral	Strongly Agree	Agree	Strongly Agree
8	Agree	Agree	Strongly Agree	Strongly Agree	Neutral	Neutral	Strongly Agree	Neutral	Strongly Agree
9	Neutral	Neutral	Strongly Agree	Agree	Agree	Agree	Strongly Agree	Neutral	Agree
10	Agree	Agree	Strongly	Strongly	Agree	Neutral	Strongly	Strongly	Strongly

			Agree	Agree			Agree	Agree	Agree
11	Agree	Agree	Strongly Agree	Strongly Agree	Neutral	Agree	Neutral	Agree	Strongly Agree
12	Strongly Agree	Agree	Agree	Agree	Agree	Strongly Agree	Agree	Strongly Agree	Agree

Open Ended

<u>Question 13: Any additional comments concerning the user interface?</u>

All the users replied to this question, they said the following:

- User 1
  "There are times when the pop-up messages do not disappear when needed or when moving on to the next page. More pictures would be helpful"

- User 2
  "Improve info please" (this information is irrelevant for the interface and is more concerned with the expert system)

- User 3
  "Include diagrams and pictures. More colour. Reference the info. Otherwise, its a great 'interface."

- User 4
  "improve content accuracy." (This information is irrelevant for the interface and is more concerned with the expert system)

- User 5
  "Great site. Fairly easy to navigate. But some of the information is not medically accurate. Diagrams and animations would make it easier to understand."

- User 6
  "There must be an option to click on the a word and go show definition rather than go to info page. For list of symptoms there must be a scroll down or multiple choice rather than scroll to left. Check spelling. Have a go to last page option. When choosing an option it must automatically go to next page rather than click continue. Diagrams must be used in definition rather words. Before starting the app a quick explanation of diabetes must be given like in story form. Interface is too large in terms of option buttons and wording we not blind. Colours must be different for different sections i.e risk factors in blue and demographic info in red. Separate the the questions into different sections rather than have them continual."

- User 7
  "Please use more diagrams and pictures for people who are lazy to read, and who remember better from pictures."

- User 8
  "No"
- User 9
  "Improve content accuracy"

Discussion

The main focus for this iteration was validating the content with the medical students in order to make certain that the information displayed is accurate. However, a considerable amount of feedback on the user interface was received; particularly concerning medical graphical aids the interface can incorporate in order to further help the user utilize their metaphorical thinking to understand the content better. One issue that was experienced during the user testing session was that some users did not understand the nature of the modularity of the system. As a result, feedback pertaining to the content of the system was given regarding the interface. However, overall the session was exceptionally useful and successful.

According to the questionnaire, the users agree that the interface is effective, with only one user disagreeing that the messages that prompt the users for input are clear. All the other users either agree or strongly agree with the effectiveness of the interface.

- <u>**Third Iteration**</u>

No.	Question
1	The characters on the computer screen are easy to read?
2	Organization of information on screen is clear?
3	Sequence of screens is clear?
4	Position of messages on screen is consistent?
5	Messages on screen which prompt user for input are clear?
6	Computer keeps you informed about what it is doing?
7	Learning to operate the system is easy?
8	Tasks can be performed in a straight-forward manner?
9	Help messages on the screen are helpful?
10	System speed is fast enough?
11	Experienced and inexperienced users' needs are taken into consideration?
12	Use of colors is effective?
13	Use of pictures is effective?
14	A person with basic computer skills can use this system?
15	What's your opinion on the length of the assessment?
16	Any additional comments concerning the user interface?

<u>Results</u>

Multiple Choice

Question No.	User 1	User 2	User 3	User 4	User 5

1	Strongly Agree	Agree	Strongly Agree	Strongly
2	Agree	Agree	Agree	Agree
3	Strongly Agree	Agree	Agree	Agree
4	Strongly Agree	Strongly Agree	Agree	Agree
5	Neutral	Agree	Agree	Agree
6	Agree	Disagree	Agree	Agree
7	Agree	Agree	Neutral	Agree
8	Agree	Agree	Agree	Strongly Agree
9	Neutral	Strongly Agree	Agree	Strongly Agree
10	Strongly Agree	Agree	Agree	Strongly Agree
11	Agree	Agree	Agree	Agree
12	Strongly Agree	Agree	Neutral	Strongly Agree
13	Strongly Agree	Agree	Strongly Agree	Agree
14	Sufficient	Sufficient	Sufficient	Sufficient
15	Agree	Neutral	Neutral	Agree

Open Ended

Question 16: Any additional comments concerning the user interface?

All the users replied to this question, they said the following:

- User 1

  "without the glitches it's user friendly indeed."

- User 2

  "In screens where descriptions are given some of the font is a little to small to be read, larger font would make the reading easier.

  I really like the fact that feedback is given through out the evaluation and regular intervals and not all at the end.

  I disagree with point 6 (The computer keeps the user informed) because it does not alert the user when the diabetes percentage goes up and I think it is very important for the user to know exactly what caused this.

  On the organization of info on the screen, on some screens there is information in the center to be read, and info in the left side bar for more information, it might help organization if it is mentioned in the central bit of information to see side bar on the left for more information or something. At first glance of the screen you wouldn't know where to begin - left side bar or central bit, and this might make navigation difficult for basic computer users.

The explanation of important terms that the system gives is very useful and is very nicely organized."

- User 3
  "Put voice over the questions."

- User 4
  "Interface is well improved-use of colour, pictures and pictures that are relevant to the information. Would most likely be easy to use for inexperienced pc users."
- User 5

Discussion
The final iteration was meant for refinement and making certain the users were satisfied with the system. The results were very positive and the users were pleased with the progress from the previous iterations. Final suggestions and feedback were given by a mixture of medical students and normal, non-computer science students.

5.3. Summary

Problems we came across.

6. Conclusions and Future Work

7. References

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8. Appendix

Appendix A: The user interface

A.1 Appendix Initial Prototype

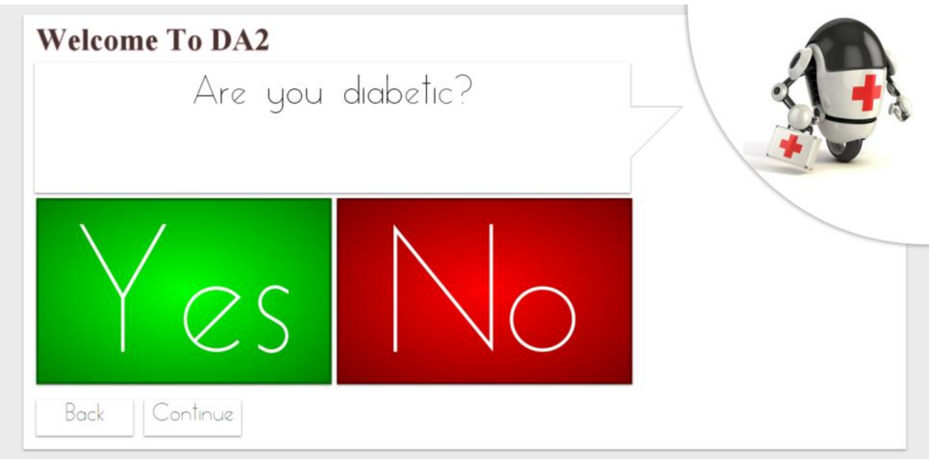


Figure 10 - Third screen of the initial prototype

Figure 11 - The dashboard screen of the initial prototype

Figure 12 - Viewing the nearest clinics in the dashboard

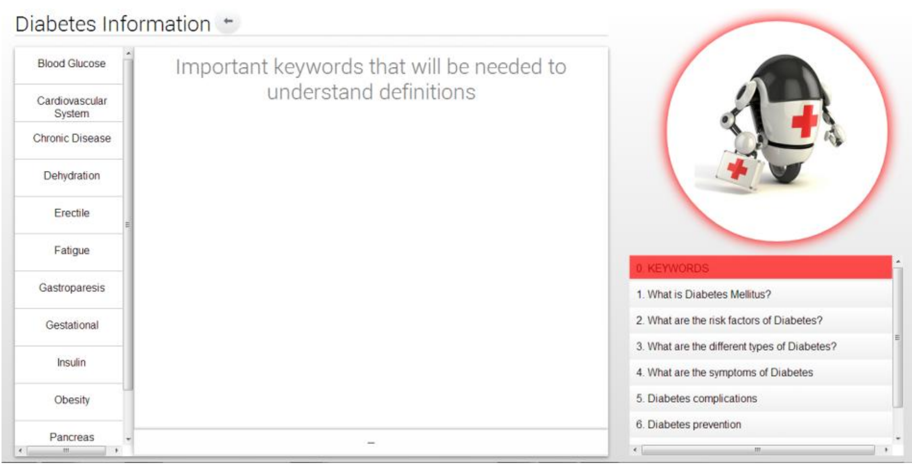
Figure 13 - The extra info implementation in the initial prototype

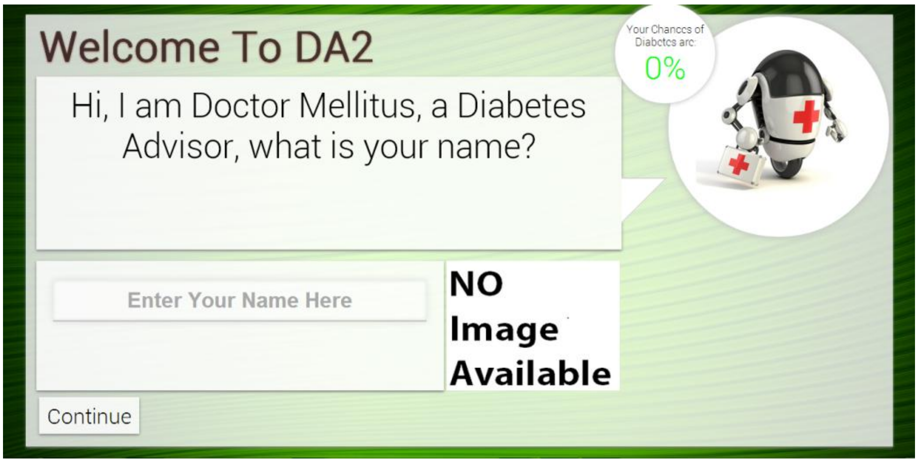
Figure 14 - The symptoms screen

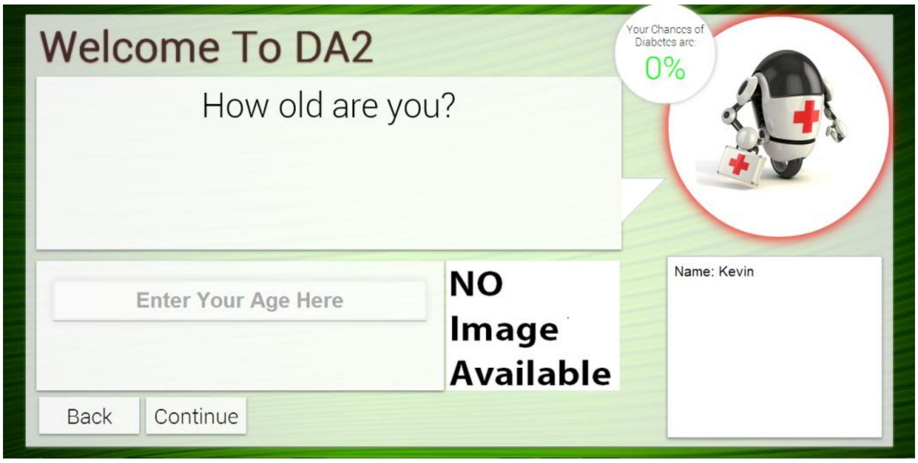
Figure 15 - The symptoms screen after scrolling down on patient panel

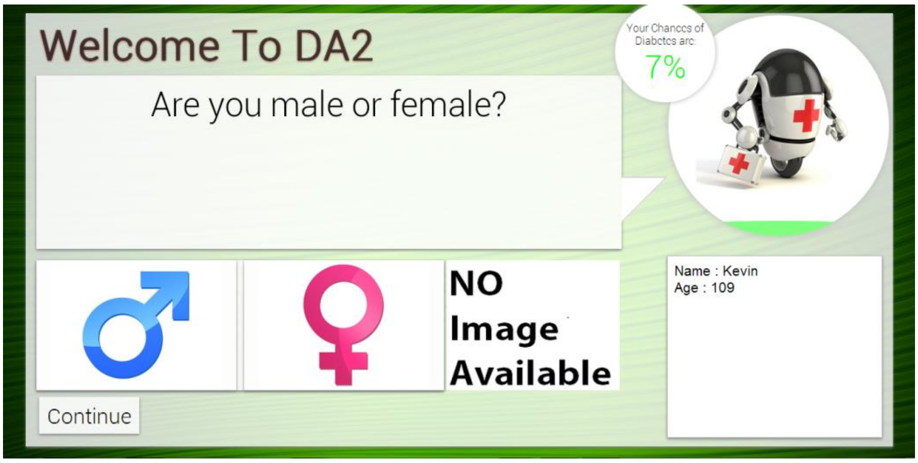
A.2. Initial prototype after the first iteration.

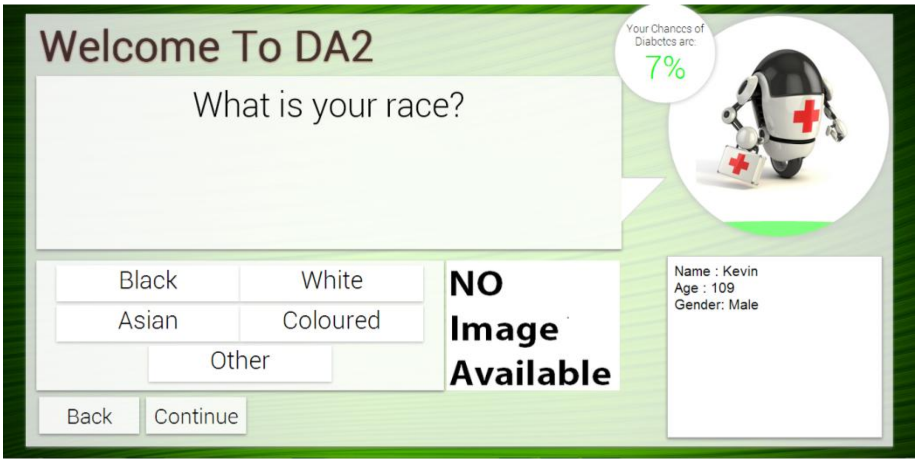
A.2. Initial prototype after the second iteration.

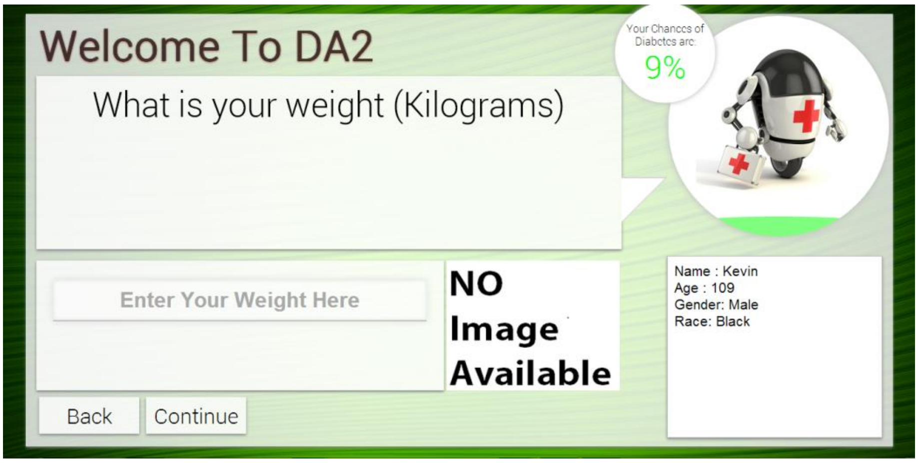


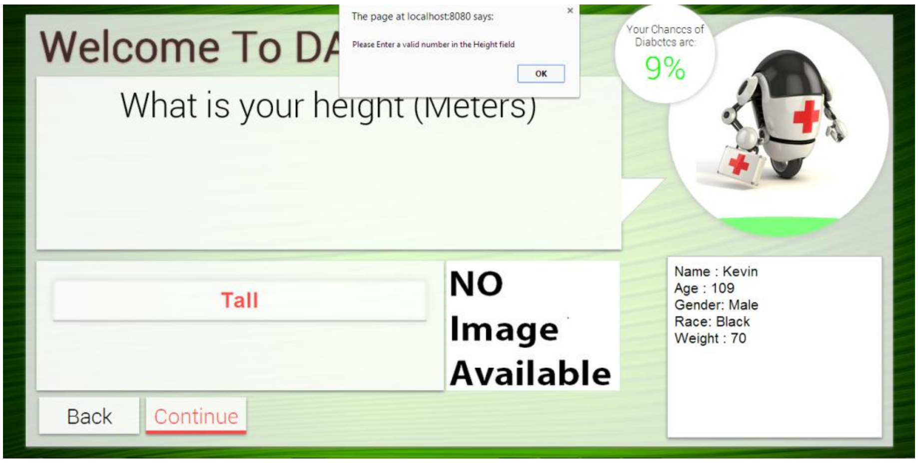

Welcome To DA2
Hi, I am Doctor Mellitus, a Diabetes Advisor, what is your name?
Your Chances of Diabetes are:
0%
Enter Your Name Here
NO Image Available
Continue

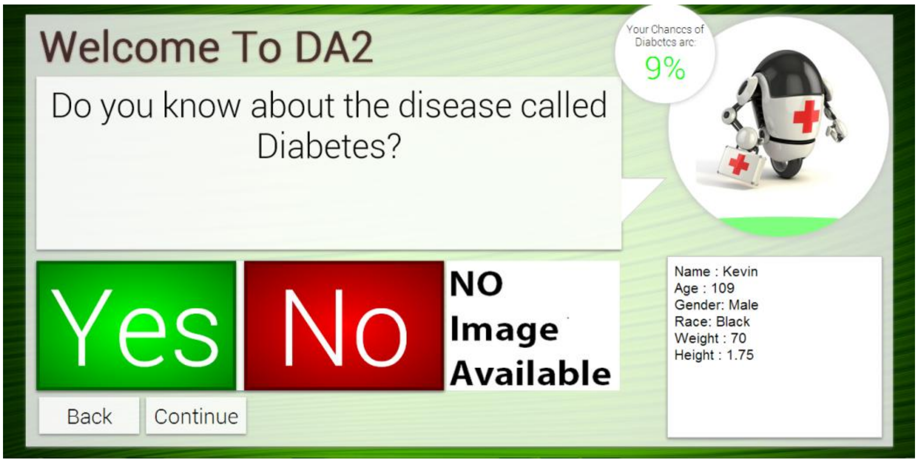

Welcome To DA2
How old are you?
Your Chances of Diabetes are:
0%
Enter Your Age Here
NO Image Available
Name: Kevin
Back
Continue

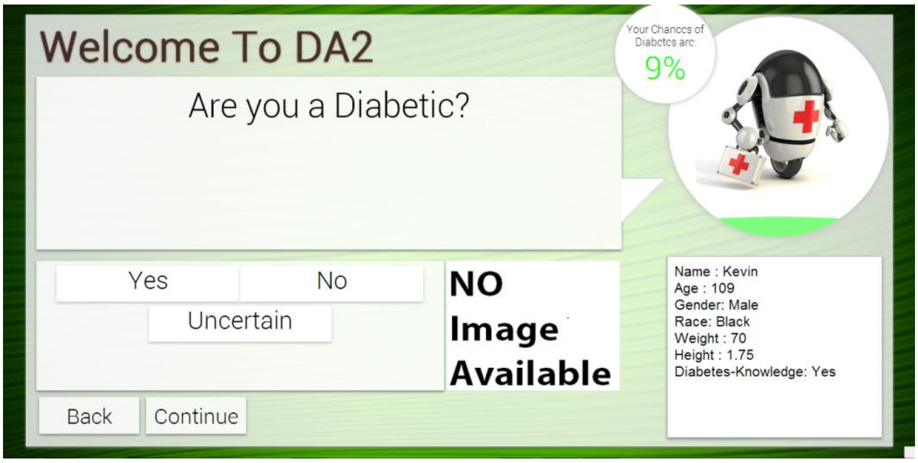

Welcome To DA2
Are you male or female?
Your Chances of Diabetes are:
7%
NO Image Available
Name : Kevin
Age : 109
Continue

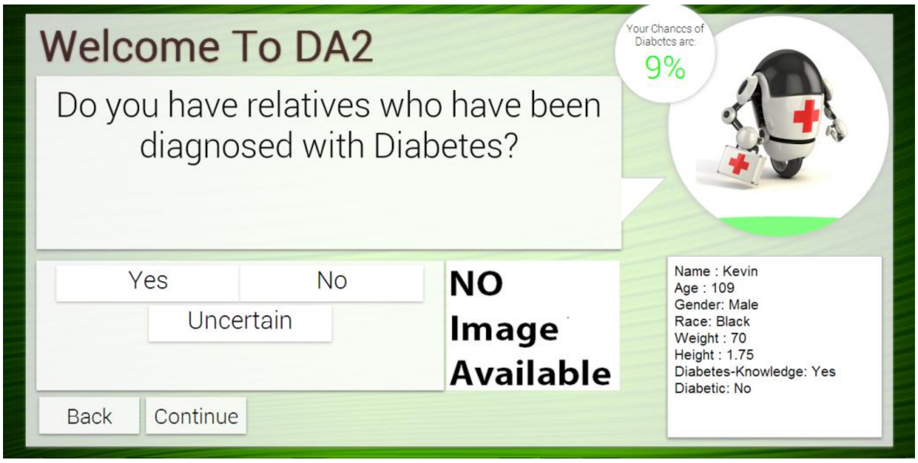

Welcome To DA2
What is your race?
Your Chances of Diabetes are:
7%
Black
White
Asian
Coloured
Other
NO Image Available
Name : Kevin
Age : 109
Gender: Male
Back
Continue

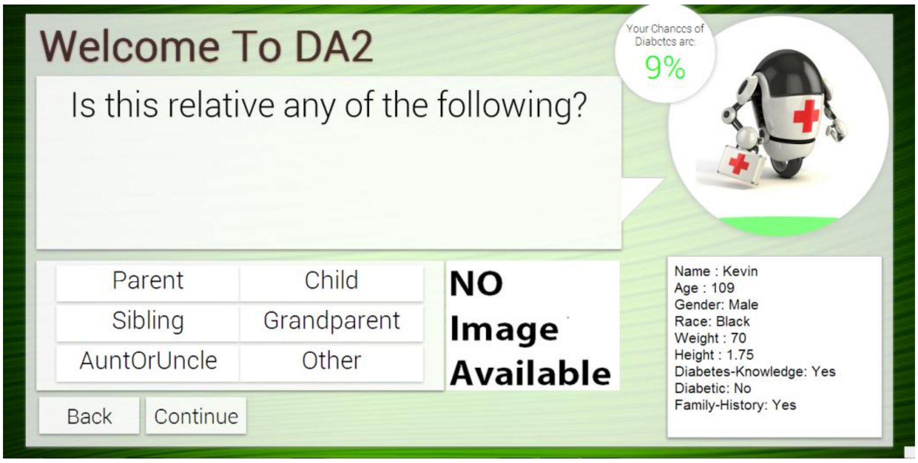

Welcome To DA2
What is your weight (Kilograms)
Your Chances of Diabetes are:
9%
Enter Your Weight Here
NO Image Available
Name : Kevin
Age : 109
Gender: Male
Race: Black
Back
Continue

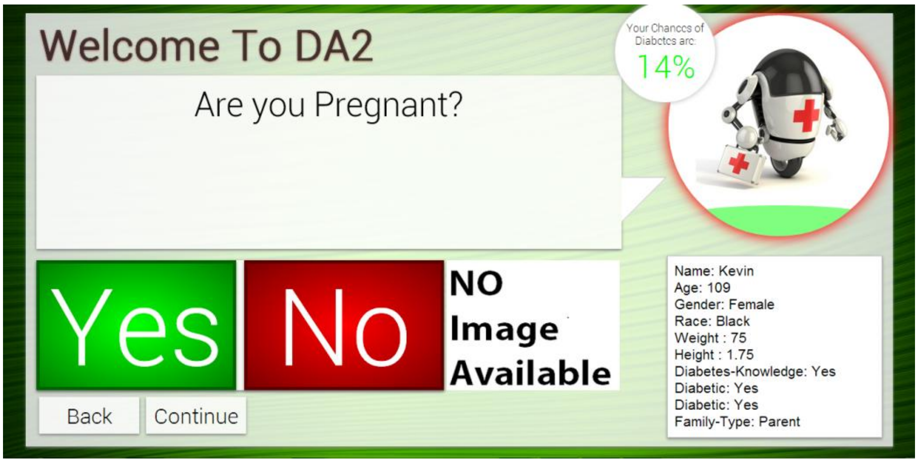

The page at localhost:8080 says:
Please Enter a valid number in the Height field
OK
What is your height (Meters)
Your Chances of Diabetes are:
9%
Tall
NO Image Available
Name : Kevin
Age : 109
Gender: Male
Race: Black
Weight : 70
Back
Continue

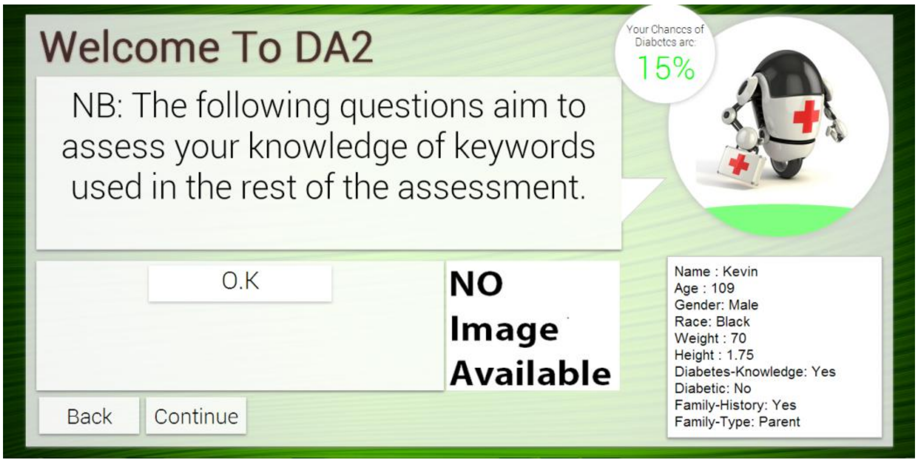

Welcome To DA2
Your Chances of Diabetes are:
9%
Do you know about the disease called Diabetes?
Yes
No
NO Image Available
Back
Continue
Name : Kevin
Age : 109
Gender: Male
Race: Black
Weight : 70
Height : 1.75

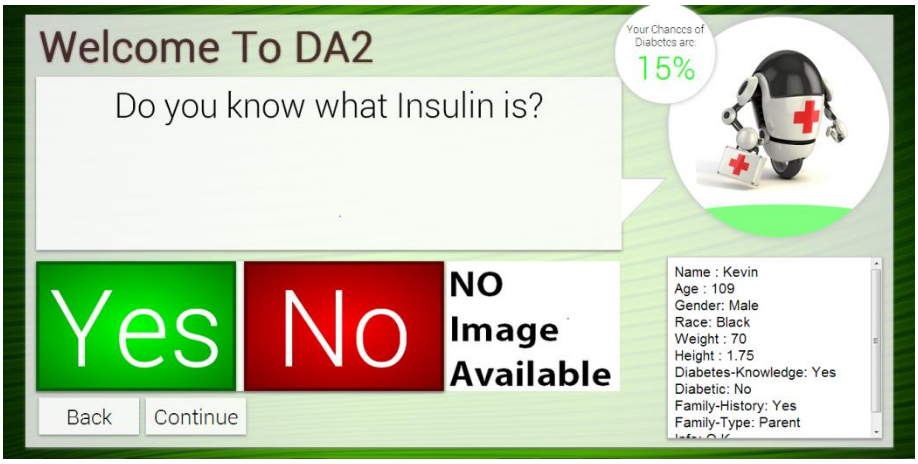

Welcome To DA2
Your Chances of Diabetes are:
9%
Are you a Diabetic?
Yes
No
Uncertain
NO Image Available
Back
Continue
Name : Kevin
Age : 109
Gender: Male
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: Yes

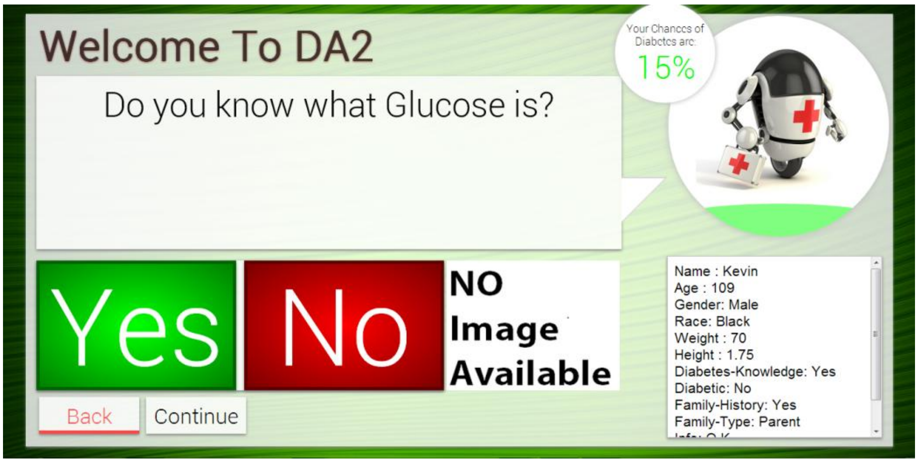

Welcome To DA2
Your Chances of Diabetes are:
9%
Do you have relatives who have been diagnosed with Diabetes?
Yes
No
Uncertain
NO Image Available
Back
Continue
Name : Kevin
Age : 109
Gender: Male
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: Yes
Diabetic: No

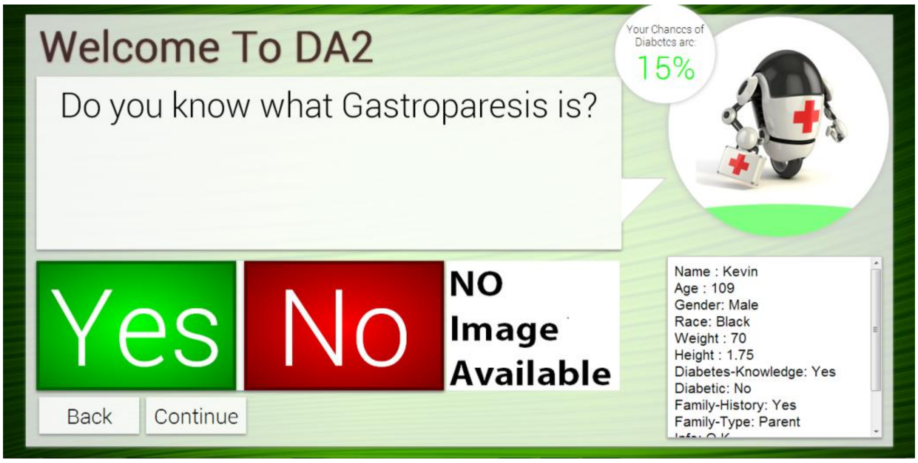

Welcome To DA2
Your Chances of Diabetes are:
9%
Is this relative any of the following?
Parent
Child
Sibling
Grandparent
AuntOrUncle
Other
NO Image Available
Back
Continue
Name : Kevin
Age : 109
Gender: Male
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: Yes
Diabetic: No
Family-History: Yes

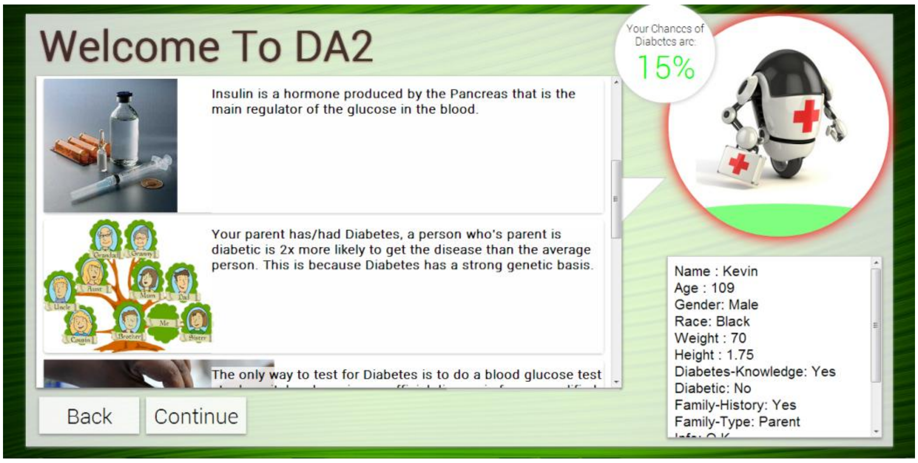

Welcome To DA2
Your Chances of Diabetes are:
14%
Are you Pregnant?
Yes
No
NO Image Available
Back
Continue
Name: Kevin
Age: 109
Gender: Female
Race: Black
Weight : 75
Height : 1.75
Diabetes-Knowledge: Yes
Diabetic: Yes
Diabetic: Yes
Family-Type: Parent

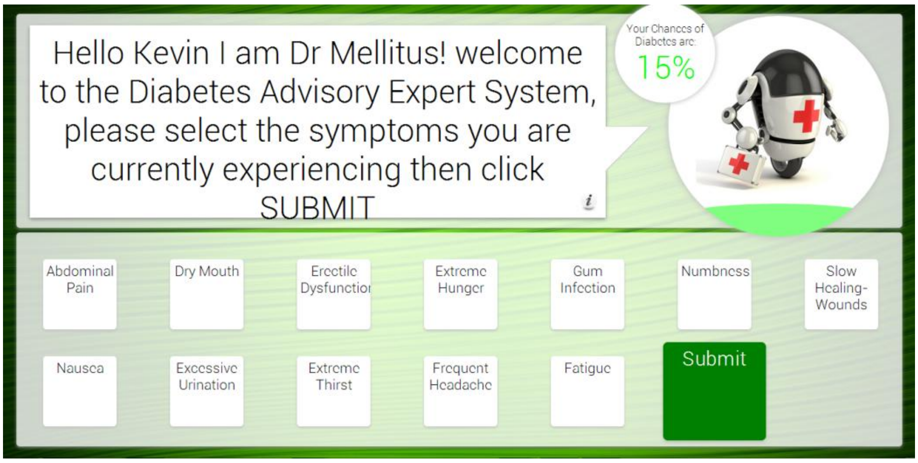

Welcome To DA2
Your Chances of Diabetes are:
15%
NB: The following questions aim to assess your knowledge of keywords used in the rest of the assessment.
O.K
NO Image Available
Back
Continue
Name : Kevin
Age : 109
Gender: Male
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: Yes
Diabetic: No
Family-History: Yes
Family-Type: Parent

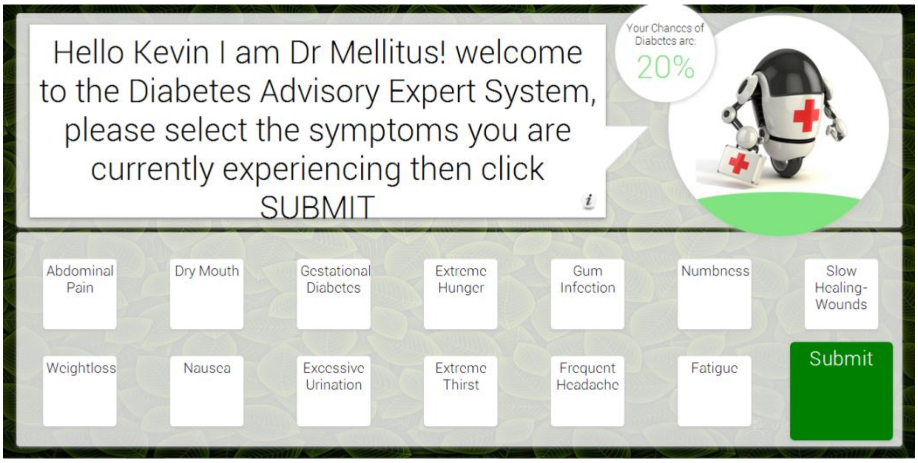

Welcome To DA2
Your Chances of Diabetes are:
15%
Do you know what Insulin is?
Yes
No
NO Image Available
Back
Continue
Name : Kevin
Age : 109
Gender: Male
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: Yes
Diabetic: No
Family-History: Yes
Family-Type: Parent

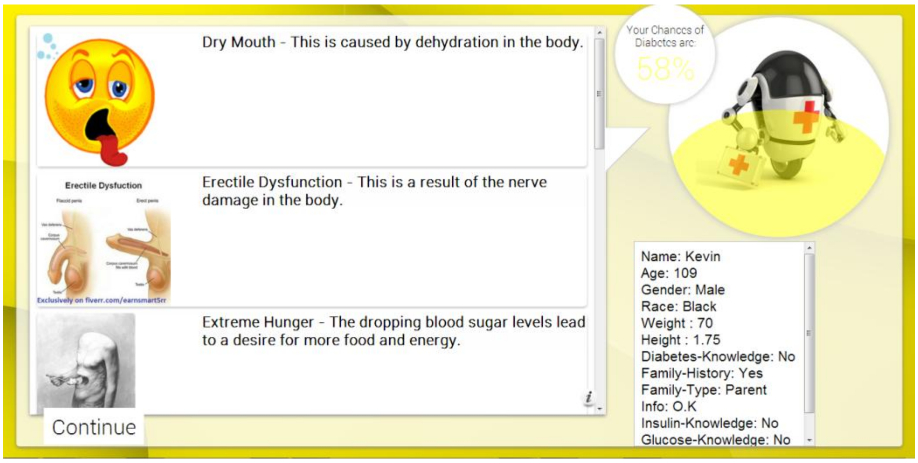

Welcome To DA2
Do you know what Glucose is?
Yes
No
NO Image Available
Back
Continue
Your Chances of Diabetes are:
15%
Name : Kevin
Age : 109
Gender: Male
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: Yes
Diabetic: No
Family-History: Yes
Family-Type: Parent


Welcome To DA2
Do you know what Gastroparesis is?
Yes
No
NO Image Available
Back
Continue
Your Chances of Diabetes are:
15%
Name : Kevin
Age : 109
Gender: Male
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: Yes
Diabetic: No
Family-History: Yes
Family-Type: Parent


Welcome To DA2
Insulin is a hormone produced by the Pancreas that is the main regulator of the glucose in the blood.
Your parent has/had Diabetes, a person who's parent is diabetic is 2x more likely to get the disease than the average person. This is because Diabetes has a strong genetic basis.
The only way to test for Diabetes is to do a blood glucose test
Back
Continue
Your Chances of Diabetes are:
15%
Name : Kevin
Age : 109
Gender: Male
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: Yes
Diabetic: No
Family-History: Yes
Family-Type: Parent


Hello Kevin I am Dr Mellitus! welcome to the Diabetes Advisory Expert System, please select the symptoms you are currently experiencing then click SUBMIT
Your Chances of Diabetes are:
15%
Abdominal Pain
Dry Mouth
Erectile Dysfunction
Extreme Hunger
Gum Infection
Numbness
Slow Healing-Wounds
Nausea
Excessive Urination
Extreme Thirst
Frequent Headache
Fatigue
Submit

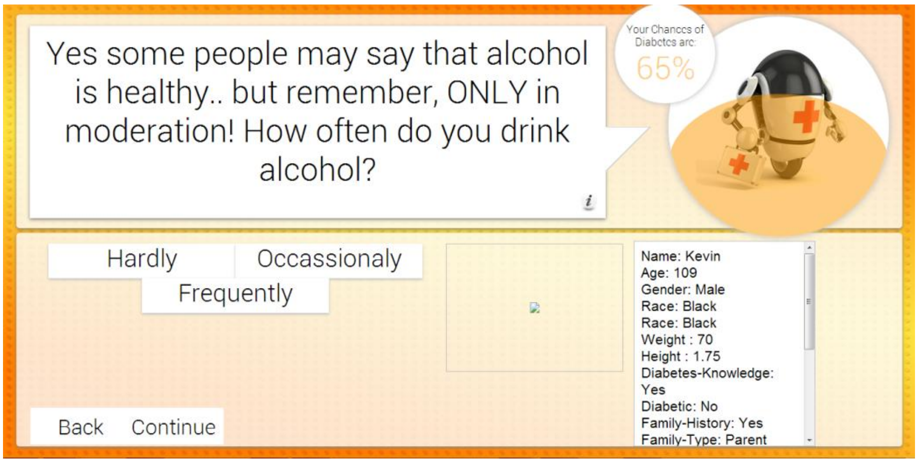

Hello Kevin I am Dr Mellitus! welcome to the Diabetes Advisory Expert System, please select the symptoms you are currently experiencing then click SUBMIT
Your Chances of Diabetes are:
20%
Abdominal Pain
Dry Mouth
Gestational Diabetes
Extreme Hunger
Gum Infection
Numbness
Slow Healing-Wounds
Weightloss
Nausea
Excessive Urination
Extreme Thirst
Frequent Headache
Fatigue
Submit

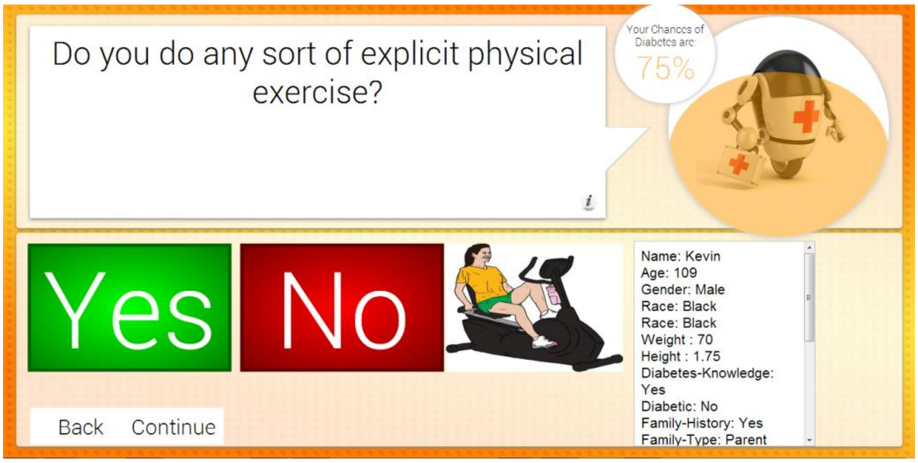

Dry Mouth - This is caused by dehydration in the body.
Erectile Dysfunction
Erectile Dysfunction - This is a result of the nerve damage in the body.
Extreme Hunger - The dropping blood sugar levels lead to a desire for more food and energy.
Continue
Your Chances of Diabetes are:
58%
Name: Kevin
Age: 109
Gender: Male
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: No
Family-History: Yes
Family-Type: Parent
Info: O.K
Insulin-Knowledge: No
Glucose-Knowledge: No

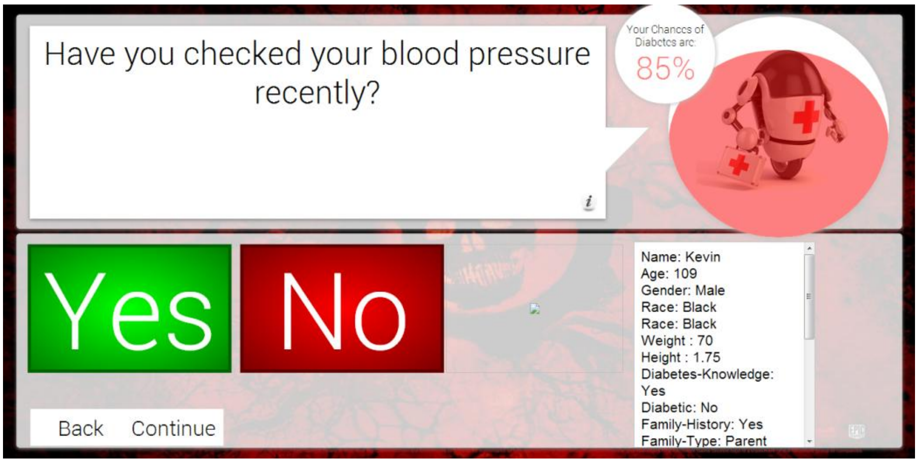

Do You smoke cigarettes?
Your Chances of Diabetes are:
58%
Yes
No
Continue
Name: Kevin
Age: 109
Gender: Male
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: No
Family-History: Yes
Family-Type: Parent
Info: O.K
Insulin-Knowledge: No
Glucose-Knowledge: No


How often do you smoke, please be honest?
Your Chances of Diabetes are:
58%
Hardly
Occassionaly
Frequently
Back
Continue
Name: Kevin
Age: 109
Gender: Male
Race: Black
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: Yes
Diabetic: No
Family-History: Yes
Family-Type: Parent


Do you consume any alcohol?
Your Chances of Diabetes are:
65%
Yes
No
Name: Kevin
Age: 109
Gender: Male
Race: Black
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: Yes
Diabetic: No
Family-History: Yes
Family-Type: Parent
Back
Continue


Yes some people may say that alcohol is healthy.. but remember, ONLY in moderation! How often do you drink alcohol?
Your Chances of Diabetes are:
65%
Hardly
Occassionaly
Frequently
Name: Kevin
Age: 109
Gender: Male
Race: Black
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: Yes
Diabetic: No
Family-History: Yes
Family-Type: Parent
Back
Continue


Do you do any sort of explicit physical exercise?
Your Chances of Diabetes are:
75%
Yes
No
Name: Kevin
Age: 109
Gender: Male
Race: Black
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: Yes
Diabetic: No
Family-History: Yes
Family-Type: Parent
Back
Continue


Have you checked your blood pressure recently?
Your Chances of Diabetes are:
85%
Yes
No
Name: Kevin
Age: 109
Gender: Male
Race: Black
Race: Black
Weight : 70
Height : 1.75
Diabetes-Knowledge: Yes
Diabetic: No
Family-History: Yes
Family-Type: Parent
Back
Continue

A.2. Initial prototype after the third iteration.

Appendix B: Code Snippets

Index.html

```
	<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">

	<html xmlns="http://www.w3.org/1999/xhtml">
	<head>
	    <title>Diabetes Advisor</title>
	    <link href="css/style1366.css" media="screen and (min-device-width:
1366px)" rel="stylesheet" type="text/css"/>
	    <link href="css/style1920.css" media="screen and (min-device-width:
1920px)" rel="stylesheet" type="text/css" />
	    <link href="css/styleF.css" rel="stylesheet" type="text/css" />
	    <link href="css/fonts.css" rel="stylesheet" type="text/css" />
	    <script src="js/JQuery.js" type="text/javascript"></script>
	    <script src="js/ui.js" type="text/javascript"></script>
	 <script src="js/detectmobilebrowser.js" type="text/javascript"></script>
	    <script src="js/script.js" type="text/javascript"></script>
	    <script src="js/scripts.js" type="text/javascript"></script>
	</head>
	<body>

	<div id="splash">
	<div id="logoC" title="Hi, I'm Doctor Mellitus, a Diabetes Advisor"><div
id="logo"><img src="images/robo.jpg"></div></div>
```

```
        <div id="theAdvisor" title="Check your chance of having diabetes"><p>Diabetes
Assessment</p></div><div id="moreInfo" title="Learn about Diabetes
Mellitus"><p>Information on Diabetes</p></div>
        <h3>Disclaimer****Use this system at your own risk, if you go decide to inject
yourself with insulin that's your own problem :-/</h3>
        </div>

        <div id="diabetesInfo">
               <div id="toolbar"><p>Diabetes Information</p> <img
src="images/icons/back.png" onclick="backtoSplash()"></div>
               <div class="speech" id="dbInfo">
               <div id="dInfoOptions"></div>
               <div id="dInfo"></div>
         <div id="dExtraInfo">
         <h1 id="keyw">Complicated Words Here</h1>
         <h2 id="keywExp">Explanation here</h2>
         </div>
               </div>
               <div id="diabetesQues"></div>
        </div>

        <div id="profile">
        <img class="imgBg" id="proImg" src="images/level/lime.jpg">
        <div><h1>Welcome To DA2</h1>
        <div class="speech">
        <span class="profileH1"></span>
        <div class="summary"></div>
        </div>

        <div class="questions">     </div><img class="illust" id="pro"
src="images/symptoms/noImage.png">
        <div id="backb" onclick="revert()">Back

        </div><div id="button" onclick="confirm()" title="">Continue</div>
        </div>

        <div class="feedback"></div>

        </div>
        </div>

        <img class="imgBg" id="symImg" src="images/level/lime.jpg">
        <div class="section" id="advisor">

        <div class="speech"><span id="advisorH1">Hello</span>

        <div id="definition"></div>
        <img id="extra" src="images/information.png">
        <div id="symptomsresultsC"></div>
        <div id="lifesummary"></div>
        </div>

        </div>

        <div class="section" id="patient">

    <!--
        <div id="menu">
        <div id="backbutton"><img src="images/icons/back.png"></div>
        <div id="nearest">Nearest Clinic</div>
        <div>Restart
        </div>
```

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        </div>
    -->

        <div id="choice">
        <h1 id="patientH1">...</h1>
        <div id="symptom">Symptoms</div>
        <div id="life">.<img src="images/risk.png"></div>
        </div>

        <div id="symptoms">
        <div class="prev"></div><div class="next"></div>
        <div id="symptomsContainer">
        </div>

        </div>

        <div id="backbL" onclick="revertL()">Back</div><div id="contButton"
onclick="confirmLifestyle()">Continue</div>
        <div id="lifestyle">
        <div class="questions"></div><img class="illust" id="lif"
src="images/symptoms/noImage.png">
        <div class="feedback"></div>
        </div>

        </div>

        <div id="chances"><p>Your Chances of Diabetes are: <span
id="pvalue"></span></p></div>
        <div id="physician">
        <div id="percentage"></div>
        <img src="images/robo.jpg">
        </div>

        <div id="ffeedbackC">
        <h1>Congratulations, you have completed the Assessment</h1>
        <div id="ffeed"><img class="imgBg" id="feedImg"
src="images/level/lime.jpg"><div class="ffeedback"><div>.:feedback
here:.</div></div></div>
    <div id="directions">
        <iframe width="100%" height="91.5%" frameborder="0" scrolling="no"
marginheight="0" marginwidth="0"
src="https://maps.google.co.za/maps?f=q&amp;source=s_q&amp;hl=en&amp;geocode=&amp;q=ne
arest+clinic&amp;aq=&amp;sll=-
33.9398,18.568611&amp;sspn=0.114074,0.264187&amp;t=h&amp;ie=UTF8&amp;hq=clinic&amp;hne
ar=&amp;ll=-
33.939942,18.568611&amp;spn=0.136718,0.219727&amp;z=12&amp;output=embed"></iframe>
        <div>
        <h1>Clinics Nearest To You</h1>
        <h2><a target="_blank"
href="https://maps.google.co.za/maps?f=q&amp;source=embed&amp;hl=en&amp;geocode=&amp;q
=nearest+clinic&amp;aq=&amp;sll=-
33.9398,18.568611&amp;sspn=0.114074,0.264187&amp;t=h&amp;ie=UTF8&amp;hq=clinic&amp;hne
ar=&amp;ll=-33.939942,18.568611&amp;spn=0.136718,0.219727&amp;z=12" style="text-
align:left">View Larger Map</a></h2>
        </div>
        </div>

    <div id="lb1">Diabetes Information</div><div id="lb2">Questionaire</div><div
id="lb3">Restart</div>
        </div>

        </body>
```

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</html>
```