ABSTRACT

This project is a design and implementation of a prototype medical expert system to aid nurses. Nurses may use the software (Diabetes Tracer) as a diagnostic and reference tool. The software can facilitate early detection and diagnosis of diabetes. The prototype uses a knowledge-based system with a front-end text-based interface that enables nurses to answer diagnostic questions and enter laboratory results. The system output is the diagnosis and treatment plan to be followed.
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BACKGROUND AND RATIONALE

Diabetes is a disease that affects 16 million Americans. Each year millions of dollars are spent in analysis, diagnosis and treatment of diabetes. Diabetes is the seventh leading cause of death in the United States and is prevalent in South Texas [8].

Due to the rise in the number of patients detected with diabetes there is a scarcity of medical practitioners specializing in diagnosis and treatment of diabetes. Insufficiency of specialized medical practitioners is felt more in rural areas of Texas where the problem of diabetes is on the rise [8]. Due to the scarcity of medical staff, there is a need for tools that jump-start and accelerate diabetes diagnosis and treatment.

There are three main types of Diabetes Mellitus: insulin dependent (IDDM or type I), non-insulin dependent (NIDDM or type II) and gestational diabetes. The system developed is a diagnostic-aid tool for nurses to accelerate and guide in diagnosis and treatment of adult onset (non-insulin dependent or type II) diabetes. The system aids the nurses to come up with diagnosis, precautions, counseling (patient and family) and follow up for the patient.

Food that a person intakes is converted into glucose (sugar), which is used as a source of energy. A hormone called insulin, secreted by pancreas, helps to break glucose to make it easily absorbable by cells. Diabetic patients either cannot generate insulin or cannot use their body’s insulin as well as they should, causing sugar build up in the blood. Diabetes can cause serious health complications like heart diseases, blindness, kidney failure and lower extremity amputations. Patients with diabetes need to maintain normal blood glucose levels at all times and early detection is the best aid.
Due to rising costs of health care, medical software has proved useful in assisting medical practitioners. Advantages of medical software include accurate prediction, correct diagnosis and less time spent in diagnosis [11].

The diagnosis of diabetic patients involves a number of complicated factors that include age, heredity, physical activity and lifestyle. A method that has been identified as particularly effective in improving decision-making strategies is an expert-system-based method. An expert system is, typically, a computer program that simulates the performance of human experts in a specific field or domain [13]. Expert systems inherently include the features of monitoring, evaluation, and decision-making processes typically required for successful implementation of a decision-based system. Monitoring and evaluation data act as feedback processes thereby helping patients and health-care workers make improvements to further increase their effectiveness.

**Justification**

The presence of technology in all aspects of life has enabled solutions to real-life problems that were either difficult or unfeasible. Intelligent inference machines based upon available data are being implemented throughout medical science. Typically expert-system-based decision-making software is employed to feed the rule-based knowledge and assist human health-care professionals to interpret and implement their decisions. It has been shown that, in association with their computer colleagues, human health-care managers have been able to improve efficiencies of their operation significantly [1, 3, 14].
The extensive implementation of expert systems in medical science has proven to successfully reduce cost [10]. The operation of typical diagnosis software could potentially revolutionize the diagnostic process the way it has impacted the commercial and industrial sectors. Thus, this project has been an expert-system-based method of decision-making for diagnosis and treatment of diabetes. The prototype expert system (Diabetes Tracker) has the potential to be useful for the health-care industry seeking ways to make health-care cost effective. Furthermore, the ultimate beneficiaries of the project are the diabetes patients. The outcome of this research project is a prototype expert system, which is intended to facilitate diagnosis, evaluation and treatment processes at various states for type II diabetes.

Benefits of Expert Systems

Like many other traditional forms of software, an expert system offers some benefits [7, 11].

1. Permits a non-expert to do the work of an expert,

2. Improves productivity by increasing work output and improving efficiency,


An expert system offers these additional benefits over conventional software [7, 12]:

1. Permits new kinds of problems to be solved, thereby making computers more useful,

2. Captures and stores valuable knowledge that might be lost due to absence of an expert,

3. Makes expert knowledge available to a wider audience, thus increasing the problem-solving ability of more people.
Expert systems, like any other software, have the potential to save money. They cost money to develop and use, but the benefits derived usually justify the cost.

**Limitation of Expert Systems**

Extracting knowledge from experts, books, and manuals is a tedious job and coding that knowledge into software takes a substantial amount of time.

Expert systems are not 100% reliable. Even with the best expert contributing to the design, expert systems are not perfect or infallible. For that reason their output must be weighed, tested and otherwise scrutinized before it is used. Human beings should always provide the final judgement [7, 10].

**Potential Users of the Prototype System**

Health care facilities may use the expert system to get a jump-start in prediction and diagnosis of diabetes. The prototype can be used by health care professionals as a tool to facilitate decision-making activities at various stages of initial symptoms recognizing, testing, and evaluating the diabetes diagnosis processes.

Health care staff can use the system in order to follow diagnostic guidelines as well as to send performance feedback to the patients. Further, the knowledge base of the prototype system can be altered and adapted for similar purposes by various health care organizations at national and local levels. The prototype system could also be useful in academia as a teaching aid and for research purposes.
C Language Integrated Production System

Some of the most commonly available tools for expert system development are shells for expert systems. A shell is a user interface that simplifies the process of developing an expert system. In simple terms, expert system "shells" are expert systems stripped of their knowledge component. Only inference and explanation mechanisms are attached to the shell. A typical shell consists of some form of knowledge-representation scheme and a ready-made inference mechanism. An example of medical Expert System shell is EMYCIN, which was originally developed for diagnosis of bacterial infection [3].

CLIPS (C Language Integrated Production System) is a knowledge-based expert system shell originally developed at the National Aeronautics and Space Administration (NASA). Though CLIPS lacks a friendly graphical user interface, it is acknowledged as one of the prominent expert system shells available today [9].

Key Features of CLIPS

Knowledge Representation

CLIPS supports three different programming paradigms: rule-based, object-oriented, and procedural. In rule-based programming, CLIPS allows knowledge to be represented as heuristics, or "rules of thumb," which specify a set of actions to be performed for a given situation. Object-oriented programming allows complex systems to be modeled as modular components. These modules could be easily reused in other components and programs. The procedural programming capabilities provided by CLIPS are similar to capabilities that are found in languages such as C, Pascal, ADA, and LISP [9].
Portability

CLIPS is written in the C language which adds to its portability and speed. It can be installed on any system that supports an ANSI-compliant C compiler. Computers on which CLIPS has been tested include Intel-based machines, Macintosh, Digital Equipment and Sun Microsystems Computers [9].

Integration/Extendibility

CLIPS has been successfully integrated with languages such as C, FORTRAN and ADA. It provides several well-defined protocols, which could be easily extended by the programmer [9, 10].

Interactive Development

CLIPS provides a simple, text-oriented development environment. Debugging aids, basic on-line help, and an integrated editor are also included. Interfaces, such as pull-down menus, integrated editors, and multiple windows are included in the environment [9].

Verification

CLIPS includes a number of features that support the verification of expert systems. Modular design and partitioning of a knowledge base are primary features supported by CLIPS to verify the expert system. Other features, such as static and dynamic constraint checking of slot values and function arguments, and semantic analyses, are also included. These features help to prevent a rule from generating an error [9].
for the project. Additionally, copies of CLIPS executables, documentation, and source code can be downloaded from the World Wide Web and can be freely used, modified, and redistributed without any restrictions. The freedom of development, along with its extensive features as an expert system shell compared to the other available shells, made CLIPS the obvious choice for this project.
Limitation of CLIPS

Graphical User Interface

While CLIPS lacks an extensive graphical user interface, a Windows-based interface with pull-down menus can be developed using standard software development tools such as Visual C++ and Visual Basic. CLIPS compatibility with other object-oriented programming tools allows easy integration with any custom developed graphical user interface [9].

Certainty Factor

CLIPS has no built-in capabilities for handling uncertainty. Uncertainty can be considered as the lack of adequate information to make a decision. Uncertainty is a problem because it may prevent from making the best decision and may even cause a bad decision. However, it is possible to incorporate uncertainty into CLIPS by placing information dealing with uncertainty directly into facts and rules, for an example:

IF

The patient has polyurea.

AND

The patient has anorexia.

THEN

There is fair possibility (0.6) that patient has diabetes.

Perform glucometer test.

Due to the features of CLIPS including portability, scalability, integration, extendibility and interactive development, CLIPS was chosen as the expert system shell
NARRATIVE

The goal of this project was to improve the diagnosis and evaluation process for diabetes by utilizing artificial intelligence technology to build and validate a prototype expert system. Medical software has played a significant role in helping both patients and medical practitioners to come up with the suitable treatment for diabetes [11]. This prototype system could be beneficial to medical professionals (such as nurses and nurse practitioners) because the system aids in producing accurate results.

As the nurse enters the system (Diabetes Tracer), the first screen shows a welcome message and informs them about the purpose of the Diabetes Tracer. The screen provides information that aids in the diagnosis and treatment of diabetes. The system then displays a general warning and normal disclaimer (Figure 1)

![Welcome screen of Diabetes Tracer](image)

Figure 1. Welcome screen of Diabetes Tracer
The second screen informs the nurse that the system will take him/her through three sections (Figure 2). The sections are “Patient Symptoms”, “Preliminary and Confirmatory Tests”, and “Patient Information”.

![Image: The system will take you through three phases]

**THE SYSTEM WILL TAKE YOU THROUGH THREE PHASES**

1. **PATIENT SYMPTOMS**
2. **PRELIMINARY TEST & CONFIRMATORY TEST**
3. **REMEDY AND TREATMENT SECTION**

*To begin, hit <Enter>*

![Image: Figure 2. Three sections of Diabetes Tracer]

**Patient Symptom Section**

In “Patient Symptoms” section of the Diabetes Tracer, the system prompts the nurse to enter information about the patient. Patient information includes name, age, sex and family history of diabetes. Next, Diabetes Tracer presents the nurse with yes/no (or y/n) questions. As each question is answered, another question is displayed. The questions presented are similar to the questions that a nurse would ask a patient during a normal visit to a medical office (Figure 3).
Figure 3. Patient information screen of Diabetes Tracer

The Diabetes Tracer presents questions about the symptoms and the nurse responds to these questions. Based on the input from the nurse, the Diabetes Tracer presents more relevant and specific questions about the symptoms of the diabetes experienced by the patient (Figure 4). For example, Diabetes Tracer prompts the nurse to answer whether patient feels excessive thirst. If the nurse entered yes/(y) as an answer, Diabetes Tracer accesses further relevant diagnostic questions, which lead to initial diagnosis.
Figure 4. Primary symptoms screen of Diabetes Tracer

Diabetic patients usually show visible symptoms like fruity smell, restlessness, shakiness and inattention. Thus the user interface of the Diabetes Tracer presents a second list of diagnostic questions to identify secondary symptoms as observed by the nurse (Figure 5). The system double-checks for the symptoms, as some patients may have all, some, or no symptoms of diabetes. For patients who do not show symptoms Diabetes Tracer does not exit there, but continues to present diagnostic questions to reaffirm that there were no errors in diagnosis. For instance, excessive thirst and frequent urination are the primary diagnostic symptoms of diabetes. If the patient experiences neither of these symptoms, the Diabetes Tracer does not stop when getting a negative response for primary symptoms. The prototype system continues and checks for secondary symptoms, aiding in diagnosis.
Preliminary and Confirmatory Tests

The second section of Diabetes Tracer is the “Preliminary and Confirmatory Tests”. This section of the Diabetes Tracer contains two preliminary diagnostic tests guides for the diabetes-glucometer test and UA dipstick test. This section also contains three confirmatory diagnostic tests guides-- fasting blood glucose test, random glucose testing and two-hour fasting glucose/ two-hour postprondial test. This section has two follow-up tests guides-- oral glucose tolerance test and glycosylated hemoglobin test (HbA1 or HbA1C). Each section of all tests has “Patient Information Section” which displays information that a patient needs to know before the test is performed. The “Why Test is Performed” section of each test informs the patient using common language, the reasons for performing the test and what the pathiophysiology test measures (Figure 6).
The "Caution" sections show warnings to nurses about the condition, that could effect and alter test results. The section also provides information about some common conditions that result in higher test values. The "Procedure" section of all tests shows nurses step-by-step instructions to perform the tests. Finally, the "Normal Values" section shows nurses the range of values to expect in the case of a healthy patient.

After the nurse follows through all these sections, the Diabetes Tracer prompts for the laboratory test results. For instance, Diabetes Tracer prompts the nurse to enter the results of a glucometer test, obtained from the laboratory test on the patient suspected to be suffering from diabetes (Figure 7).
Caution—Positive test results is not a positive indication of diabetes. The higher values could be due to rebound hyperglycemia.

Step-by-step procedure is:
1. Turn the meter on.
2. Insert contact bars of calibrator into monitor.
3. Monitor will turn on automatically and RR.R appears automatically.
4. Insert test strip, pierce patients finger with a disinfected needle.
5. Apply a drop of blood on targetted area of the strip.
6. Results will be shown on the monitor in 20 seconds, note the results.
7. Throw the strip and store the glucometer carefully.

Normal values—110-160mg/dL

Enter the values obtained?

Figure 7. Caution and Procedure sections of Diabetes Tracer

Patient Information Section

The third section Diabetes Tracer is “Patient Information”. This section asks the nurse if he/she is interested in accessing various patient information screens. Based on the patient’s requirement the nurse could answer yes/no to access various patient information screens. Different information screens provide different information catered to the diabetic patient’s need.

The “Health Care” screen provides information about diabetic patient’s need for insulin, regulation of insulin, types of insulin and allergic reactions to insulin. The screen starts with explaining the need for diabetic patients to inject insulin. It provides basic information about how insulin is extracted and measured. Information about types of insulin, their onset, peak and duration of each type is listed. Information about how to identify allergic reactions to insulin is also provided (Figure 8).
Figure 8. Health-care screen of Diabetes Tracer

The “Patient Education” screen provides information about pathophysiology of diabetes. The content of the screen helps the nurse explain to the patient in that deficiency of insulin is the reason that patient is suffering from diabetes. This screen provides information regarding long-term and short-term complications of the disease (Figure 9).
Figure 9. Patient education screen of Diabetes Tracer

The “General Measures” screen provides general suggestions that diabetic patients must follow. It mentions life style changes that the patient needs to make, like exercising regularly and following a prescribed diet regime. Information provided in this screen include insulin dosage, scheduling of dosage, caution while following insulin dosage and treating insulin reaction. The screen also emphasizes the importance of proper foot care for diabetes patients (Figure 10).
DO YOU WANT TO CHECK GENERAL MEASURES SCREEN
Information about health maintenance, diet and control.
Please enter yes/no.

yes
A person with diabetes mellitus must play a major role is self management. Patient education guidelines must be followed since diabetes is a lifelong disease.

---Become familiar with the diabetes and how it effects the body---
1. Visit physician on a regular basis.

---Maintain health at optimal level---
1. Maintain a consistent daily routine.
2. Get adequate rest and sleep.
3. Exercise regularly and consistently.
   a. Avoid spurts of arduous exercise before meals.
   b. Have some form of carbohydrate like sugar, candy, orange juice available during exercise period.

---Follow the prescribed dietary regimen---
1. Eat three or more measured meals each day.
   Plan ahead for prescribed meals and snacks.
2. Patient need to be thoroughly familiar with

Figure 10. General measure screen of Diabetes Tracer

The "Patient Activity" screen provides exercise recommendations and the circumstances when vigorous exercise should be avoided. Cautions that need to be taken before starting an exercise program are also mentioned. The "Dietary Recommendation" screen shows the dietary recommendations for the diabetic patient. It provides information about the different food groups. Recommendations about which food groups should constitute what percentage of a diabetic patient diet are also listed. The screen also shows a sample of a diabetic diet (Figure 11).
Exercise Recommendations - Exercise positively affects the level of blood glucose by increasing metabolism and over a extended period of time can increase insulin resistance

1. Exercise program should be started after an appropriate health exam which focuses on heart, blood vessel, eye and nervous system.

2. A graded exercise test should be performed on patients at high risk for cardiovascular disease.

3. Patients who have complications of the eye, kidney and autonomic neuropathy should avoid strenuous exercise

4. Patient with peripheral neuropathy should take precautionary measures such as proper footwear.

5. For patients on insulin therapy, the following

Figure 11. Patient activity screen of Diabetes Tracer

The “Counseling screen” provides a contingency plan for the family members or caretaker of the diabetic patient in case of hypoglycemia. It also has information about managing a diabetic patient in case of illness (Figure 12).
Figure 12. Counseling screen of Diabetes Tracer

The “Follow-up” screen displays follow-up schedules for the patient. It shows information about follow-up schedules for patients beginning insulin therapy and patients who are undergoing major changes in insulin dosage. Information regarding follow-up schedules for patients on medical nutritional therapy, oral glucose lowering agents and general insulin therapy are also displayed (Figure 13).
Figure 13. Follow-up screen of Diabetes Tracer

Thus after taking input from a series of diagnostic questions, laboratory test results and input on patient health care screens, the Diabetes Tracer displays the probable diagnosis. Diabetes Tracer analyzes combinations of patient symptoms as input by the nurse (Figure 14).
The Diabetes Tracer’s output screen discusses the preliminary diagnosis based on the patient symptoms. Diabetes Tracer then analyzes the test results of various diagnostic tests performed and outputs a confirmatory diagnosis. Diabetes Tracer displays additional screens containing vital information about diabetes treatment. Only the necessary screens are displayed based on the nurse’s input (Figure 15).
Figure 15. Diagnosis and recommendation screen of Diabetes Tracer

Since diabetes is a life-long disease and the diagnosis process is extensive, the Diabetes Tracer acts as a reference guide to medical practitioners. There is no cure for diabetes and only way to treat diabetes is educating patients to manage their condition. Diabetes Tracer helps medical practitioners in educating patients in the management of diabetes through an extensive database of educational screens.
ENVIRONMENT

Diabetes Tracer is designed to be a single-user system. The expert system was developed using CLIPS (Version 6.0). CLIPS is written in the C language for portability and speed, and can be installed on many different computers without code changes. Copies of CLIPS executables, documentation, and source code can be downloaded from the World Wide Web at http://www.ghg.net/clips.

System Requirements for CLIPS 6.10

Following are the system requirement for developers and the user.

- Intel Pentium, 100 MHz processor or higher.
- Windows 3.1, 95 / 98/ 2000 or Windows NT workstation operating systems.
- Minimum 16 MB RAM.
- 10 MB available hard drive space.
- SVGA color monitor.

Requirements to Run Diabetes Tracer

- Clipswin.exe and cliphlp.hlp (optional) files installed on the computer.
PROCEDURE

The following steps were followed to develop the Diabetes Tracker.

1. Data was gathered on diagnosis and evaluation processes for diabetes.

2. Various domains of medical science were classified and structured to organize the acquired information (i.e. facts and rules), according to the CLIPS expert system syntax.

3. Prototype expert system was developed using the CLIPS expert system shell.

Method and Procedure

The methods and procedures used in this project are divided into two broad sections. The first section identifies the sources of data and knowledge acquisition, while the second section describes the method of data analysis, system development and validation process for the prototype expert system.

The methodology used for this project is prototype development (Figure 17), which is case specific. Upon modification, the prototype may be used by hospitals as well as for academic purposes, thereby permitting a dual audience for the final product.

This project is a control problem that requires determination of control decisions based upon real-life feedback data. Control problems include processes that require interpretation, monitoring, planning and diagnosis. The expert system requires determination of the inference engine based upon the type of problem. An inference engine of an expert system is a component that draws conclusions to execute the highest probable rule, based upon the facts in the available knowledge database [11]. This concept could be represented by Figure 16.
The design of this project is an expert system prototype. An expert system prototype refers to a scaled-down version of a larger system. It typically includes representation of knowledge captured in a manner that enables quick inference and includes the major components of the expert system to function on a rudimentary basis.

Below provided Figure 17 illustrates this process followed for the development of Diabetes Tracer (expert system prototype).
Figure 17. Steps followed for development of expert system prototype.
Knowledge Acquisition

Recognizing knowledge sources

The data sources that were used for Diabetes Tracer are:

1. Books and reference manuals (basic knowledge).
2. Operational knowledge acquired from interviewing registered nurses regarding diagnostic tests performed.

Interviewing experts

Initially, information was collected from various medical books about causes, types, complications, signs and symptoms of diabetes. Basic information was acquired about diagnostic procedures, treatment, risk factors involved and medication used for the treatment of diabetes using medical reference books. Information about risk factors and nutritional need of diabetic patients was also acquired. Various relevant online resources like the American Diabetic Association homepage were utilized.

The main knowledge sources for this project were the operational information from various medical practitioners. Once basic information was collected about diabetes mellitus, different experts in the field of medical science were interviewed. There are three main types of Diabetes Mellitus: insulin dependent (IDDM or type I), non-insulin dependent (NIDDM or type II) and gestational diabetes. This prototype Expert System for diabetes diagnosis was developed for adult onset (non-insulin dependent or type II). There are complications associated with type II diabetes. Knowledge acquisition about complications was acquired by interviewing medical practitioners specializing in the complications of diabetes.
Once theoretical information was gathered on type II diabetes, knowledge about the applied aspects of diabetes was assembled. Registered nurses were interviewed concerning most common symptoms experienced by diabetic patients. Information was obtained as to the sequence of questions asked and the procedures followed by medical practitioners in arriving at an initial diagnosis of type II diabetes. An example of the question asked of a medical professional is: "How do medical practitioners ascertain that the cause of a certain symptom such as low glucose is diabetes or another factor like a high-protein diet?"

After initial determination that the patient is suffering from diabetes, nurses ask other more deterministic questions and perform tests to ascertain that the patient is suffering from diabetes. Knowledge acquisition about those deterministic questions and tests performed were done through the interviewing process.

Once diagnostic procedures were established, those procedures were confirmed by follow-up interviews with medical professionals. The reason for selecting different sources of medical information was to comparatively verify the completeness of the documentation of diagnosis and evaluation cycles by different medical practitioners. The knowledge acquisition and following downstream process is represented in Figure 18.

<table>
<thead>
<tr>
<th>INPUT FROM EXPERT</th>
<th>PROCESSOR</th>
<th>OUTPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inference Strategies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reasoning Processes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Justification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explanation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge Engineer</td>
<td>Data from the knowledge base</td>
<td></td>
</tr>
</tbody>
</table>

Figure 18. Knowledge acquisition from domain expert [4].
Development of System

Organizing Knowledge

The information obtained from different medical sources and experts was structured for analysis and was converted into pseudocode.

The information obtained on type II diabetes from the experts was in the form of tape-recorded interviews and books suggested by medical experts. This knowledge from the interviews was extracted and organized in the form of pseudocode. An example of the process is:

On February 15 2000, in an interview with a registered nurse, the following statement was recorded:

“When a patient comes in we make him/her fill the relevant forms. Usually the patient will complains that he feels dizzy now and then, and he is thirsty all the time even if he drinks eight glasses of water. This gives us a little bit of impression that patient might have diabetes and we ask further questions.”

This information is translated to “Patients experience dizziness and excessive thirst as primary symptoms. More questions need to be asked from the patients about symptoms”. This information is translated into rules according to CLIPS syntax (Figure 19 and Figure 20).

<table>
<thead>
<tr>
<th>RULE</th>
<th>IF (ANTECEDENT)</th>
<th>THEN (CONSEQUENT)</th>
</tr>
</thead>
</table>
| Initial diagnosis | 1. Patient complains about dizziness.  
|                 | 2. AND patient complains about being thirsty.         | 1. Discuss further symptoms.                      |

Figure 19. An example of an organizing knowledge in rule form.
(defrule Initial Diagnosis
  (and (Patient complains dizziness) (Patient complains thirsty))
  =>
  (assert (Discuss further symptoms))
  (printout t " " crlf))

Figure 20. An example of converting organized knowledge to CLIPS syntax.

A similar process is adapted for extracting information from the books, that is the knowledge was converted into pseudocode and then converted to CLIPS syntax. An example of CLIPS syntax to check results of glucometer test is shown in Figure 21.

(defrule vis36
  ?patientgluco <- (glucop ?glucopat)
  (test (<= 120 ?glucopat))
  =>
  (assert (HIGH GLUCOMETER))
  (retract ?patientgluco))

(defrule vis37
  ?patientgluco <- (glucop ?glucopat)
  (test (> 120 ?glucopat))
  =>
  (assert (NOT HIGH GLUCOMETER))
  (retract ?patientgluco))

Figure 21. An example of CLIPS syntax developed by gathering information from books.
System Development

The development process was:

(1) Developmental tools and system requirements for building the prototype were identified.

(2) Method of data analysis was determined.

(3) Rules were incrementally built to solve the problem.

Method of knowledge Representation

In CLIPS, knowledge can be encapsulated in rules and objects. Furthermore, rules can match patterns or objects as well as facts. In addition, objects can operate independently of rules. A rule-based system was developed in this project. The reason for using a rule-based approach was its ease of encapsulation of knowledge and future expandability [7, 10]. The prototype used backward chaining or the data-driven approach, which starts with available information and draws conclusions from that information. An example of the approach is shown in Figure 22, if the patient is older than 40, the blood glucose level is above 120, the patient shows the symptoms of polyurea, and if the glucose tolerance test is positive, then the patient is suffering from type II diabetes. In this example, the system starts from the initial data of patient’s age being over 40 and blood glucose level greater than 120 and symptoms of polyurea and positive glucose tolerance test. Then based on those data the system reaches the conclusion of type II diabetes.
Figure 22. Knowledge-base lattice used showing backward chaining.

Rules within the knowledge base were written in "IF" (antecedent) and "THEN" (consequent) statements. The rule-based representation using the same example as used to explain backward chaining approach is shown in Figure 23.

```
IF
Patient age is > 40
AND Patient Urinates Frequently
AND Glucose Tolerance test is positive.
THEN
The patient has Adult Onset Diabetes.
Treatment suggested.
```

Figure 23. Rule based representation in CLIPS.
Figure 24 shows how the data (information and test results) pertaining to diabetes (diagnosis, treatment and nutritional management) are structured according to CLIPS syntax.

IF  
Positive glucometer test  
AND fasting blood sugar (FBS) > 140mg/dL on two occasions  
AND patient experiences frequent infections

THEN  
The patient has type II Diabetes.  
Patient education.

IF  
Patient has type II Diabetes  
AND patient has frequent hypoglycemia

THEN  
Suggest general measures (home glucose monitoring)  
Suggest regular examination for complication like retinopathy, neuropathy and nephropathy.

IF  
Patient has type II Diabetes  
AND patient has frequent hyperglycemia

THEN  
Suggest diet consisting of carbohydrate-70%, protein-20%, Fat-<10%.  
Specifically prohibit sugar  
Periodic measurement of hemoglobin A1c to assess overall glycemic control.

Figure 24. Examples of CLIPS rules.
Testing

Knowledge was formatted in various ways to utilize the template features of the system shell. Initially, testing was done on a small section of data. The data was structured in various formats to find out the best way to encapsulate knowledge and create a knowledge base for the system. Similarly a small section of data was utilized to determine the validity of the syntax and verify the structure of the data.

Trial runs on the same section of data helped to determine any syntax errors and programming problems. Finally, upon determination of the validity of the syntax and program execution, all of the information was converted into "IF/THEN" rules. To facilitate the management of data, the rules were divided into three subgroups according to various diabetes diagnosis stages: diagnostic symptoms, diagnostic test and patient education. The “Diagnostic Symptom” section contained information regarding diagnostic questions for evaluating symptoms of the patient. The “Diagnostic Test” part contained information about performing various diagnostic tests. The “Patient Education” part contained information regarding patient information about diabetes management.

System Validation and Testing

The final stage in developing an expert system involved validation of the system. The process of confirming accuracy and effectiveness of the methodology, as applied to the product, is known as verification [4]. Verification means building the system right, that is, ensuring that the system correctly implements the specification. Validation determines if the knowledge base conforms to its design requirements and the software syntax from which it is built [4]. System validation and testing was done hand-in-hand
with the implementation stage. Its purpose was to uncover any errors in the operational prototype before the prototype was taken to a full-scale system.

Upon completion of each phase of the prototype, a nursing educator tested the prototype for errors. Whenever any error occurred, appropriate changes were made to correct them. The nursing educator tested the prototype again. If any further problems arose, revisions were made to correct them. The cycle was repeated until the full-scale system evolved.
RESULTS

The Diabetes Tracer (expert system prototype) provides interactive text-based screens to accept input from the user (nurses), in the form of laboratory test results and answers to the presented diagnostic questions.

The first section of the Diabetes Tracer presents the nurse with diagnostic questions to evaluate symptoms experienced by the patient. The system then prompts the nurse for answers to be entered yes/no (y/n) format. In the second section the system guides the nurses through series of tests performed in diabetes diagnosis process. Information about the procedure, reasons for performing the test, cautions and normal laboratory test values is provided in this section for each laboratory test. This section accepts laboratory test results as input. Last section of the system asks the nurse if he/she is interested in accessing various patient information screens. Information useful to the diabetic patient like pathophysiolgy of disease, insulin dosage, lifestyle changes, dietary recommendations, exercising recommendation and contingency plan is provided in these screens. Based on input from the nurses the output of the Diabetes Tracer is diagnosis, recommended treatment, precautions and general counseling.

Nurses can use the Diabetes Tracer as diagnosis aid and reference tool to facilitate treatment and counseling procedure. Step-by-step description of laboratory test could aid non-expert nurse to follow the procedures for performing diabetes diagnostic tests. The Caution and Normal Value sections could prevent errors and misinterpretations of laboratory test results. A diabetic counselor could also use the Diabetes Tracer counseling screen for instruction and guidance.
FUTURE WORK

The prototype could be extended to provide diagnosis, treatment options and patient/parent counseling to other types of diabetes, i.e. type I (children’s diabetes) and gestational diabetes.

The prototype developed in this project does not have an extensive graphical user interface; neither does it has World Wide Web (Web) deployment features. A graphical user interface is desirable because of ease of input. Development of a graphical user interface could be done for future research and enhancement of the project. With present-day software technology, developers have full flexibility to take advantage of the latest Web development techniques, including dynamic Hyper Text Mark-up Language (HTML), dynamic database calls, graphic design, and multimedia.

Further studies could investigate the use of expert systems in other areas of medical and nutrition science, such as creating expert systems for nutrition science laboratory experiments, patient diet plans or management training for medical professionals.
BIBLIOGRAPHY


