THE NUTRITION ADVISOR EXPERT SYSTEM

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Abstract. The Nutrition Advisor Expert System (NAES) is an expert system written in the C Language Integrated Production System (CLIPS). NAES provides expert knowledge and guidance into the complex world of nutrition management by capturing the knowledge of an expert and placing it at the user's fingertips. Specifically, NAES enables the user to: (1) obtain precise nutrition information for food items, (2) perform nutritional analysis of meal(s), flagging deficiencies based upon the United States Recommended Daily Allowances, (3) predict possible ailments based upon observed nutritional deficiency trends, (4) obtain a top-ten listing of food items for a given nutrient, and (5) conveniently upgrade the database. An explanation facility for the ailment prediction feature is also provided to document the reasoning process.

INTRODUCTION

The Nutrition Advisor Expert System (NAES) is an expert system written in the C Language Integrated Production System (CLIPS). The purpose of NAES is to emulate human expertise in the complex problem domain of nutrition analysis. NAES is a user-friendly, practical expert system with real application potential, e.g., nursing homes, hospitals, doctor's offices, or home use.

NAES allows even a novice user to:

(a) quickly and easily obtain nutrition information on food item(s);
(b) perform nutritional analysis on meal(s);
(c) predict potential ailments based upon nutritional deficiency trends;
(d) generate a top-ten listing of food items for a given nutrient;
(e) conveniently upgrade the database of nutrition knowledge.

NAES consists of a working memory of facts and rules in a knowledge base. The user can easily enter new food item facts into the database or delete existing facts. Consequently, the system can improve its performance with time. The system also features an explanation facility for the ailment prediction module. This important facility provides documentation detailing the reasoning process.

In the development of this system, several artificial intelligence/expert system (AI/ES) techniques were utilized to increase system efficiency and reliability, e.g., fuzzy sets, certainty factors, uncertain evidence, modular design, and efficiency techniques in coding design. The methods by which some of these techniques were implemented in NAES is discussed in detail within the 'System Features' section of this paper.

An expert system should be characterized by good performance, adequate response time, good reliability, understandability, and flexibility (Giarratano and Riley 1989). NAES possesses

each of these important qualities. It is capable of performing quick expert nutritional analysis with a high degree of reliability and understandability. System flexibility is provided by a convenient and efficient mechanism for modifying the database of nutrition knowledge.

INSTALLATION GUIDE

NAES was written using CLIPS software, version 4.2 for the IBM PC. The software is available from the authors on a 5 1/4 inch diskette. In order to run the program, CLIPS must first be installed on your computer. If it is not already installed on your hard drive, copy the CLIPS diskette(s) into a sub-directory named 'CLIPS'. Run CLIPS by typing, 'CLIPS'.

Once CLIPS has been installed on your computer, you are ready to run the Nutrition Advisor Expert System. Insert the NAES program diskette into drive A and from the CLIPS directory on your hard drive type, 'copy a:nut .' <RETURN>. This will copy the program into the CLIPS directory of your hard drive. Next, type 'CLIPS' <RETURN>. This will bring up the CLIPS environment. NAES can then be loaded into the system by typing 'load "nut"' <RETURN>. The program will load in about forty seconds, depending of course on your computer system. When the CLIPS' prompt returns, the system is loaded and ready to run. Run it by typing '(reset)' <RETURN>, and then '(run)' <RETURN>. The (reset) command initializes the system and the (run) command starts program execution.

A main menu should appear with the following six options:

(1) Food Item Information

(2) Dietary Analysis of Meal(s)

(3) Ailment Prediction Based on Nutritional Deficiencies

(4) Top-Ten

(5) Database Update

(6) Exit

To select an option simply enter the menu number followed by the <RETURN> key.

SYSTEM FEATURES

This section provides a detailed discussion of each of the features offered by the system. There are six menu options. A step-by-step explanation of how to use each menu option follows along with a discussion of implementation details.

The first menu option is 'Food Item Information'. Select this option if you are interested in obtaining nutrition information for a given food item. When you select this option you will be prompted to enter the name of the food item. Enter the food item and press <RETURN>.

This module operates in a straightforward manner. The food item name entered by the user is simply matched against the foot item name field in the list of facts. The template used for food items is:

(item <food name> <calories> <calcium> <iodine> <iron> <magnesium> <phosphorus> <sodium> <vitamin A> <vitamin B1> <vitamin B2> <vitamin B6> <vitamin B12> <folic acid> <niacin> <vitamin C> <vitamin D> <vitamin E>)

If a match is found, the corresponding nutritional multi-field values for a standard serving are extracted by the system and displayed on the screen. If, on the other hand, the food item is not present in the database, the user is informed accordingly and instructed to use menu option five,

'Database Update', to update the database. Table 1 shows a sample run of this menu option.

Enter Food Item: beef

"beef"

Calories	1481
Calcium	50 mg
Iodine	0 mg
Iron	15 mg
Magnesium	131 mg
Phosphorus	634 mg
Sodium	271 mg
Vitamin A	181 IU
Vitamin B1	0.23 mg
Vitamin B2	0.8999 mg
Vitamin B6	2 mg
Vitamin B12	0 mcg
Folic Acid	0.07 mg
Niacin	18.1 mg
Vitamin C	0 mg
Vitamin D	0 IU
Vitamin E	0.6 mg

Table 1. A run of 'Food Item Information'

The second menu option is 'Dietary Analysis of Meal(s)'. Select this option if you are interested in obtaining nutrition information for a meal or meals. When you select this option you will first be prompted to supply some personal data, i.e., name, age, and gender. If the gender is female and the age is greater than ten, the system will also inquire if you are pregnant. There are fifteen different categories that are utilized based upon sex and age. This information is necessary to determine the appropriate caloric and United States Recommended Daily Allowances (USRDA) guidelines.

Once this information is provided, you will be prompted to enter the name and relative quantities of food items that you either have consumed or plan to consume. This information is categorized on two levels. The first categorization that takes place references the time of day that consumption occurs (breakfast, lunch, or dinner). The second categorization that occurs relates to the nutritional food group that the food item belongs to (meat, dairy, fruit and vegetable, or bread and cereal). If you wish to skip an entry, simply press <RETURN>. Once you have entered all of the necessary information, the system will quickly analyze the nutritional content of your meal(s) and display any nutritional deficiencies based upon your specific USRDA requirements.

The implementation of this module is more complex than that of the first menu option. Each entered food item is asserted into the database in the fact form:

(dayfood <food name> <quantity> <breakfastllunchldinner>).

The <quantity> field in this fact represents the fuzzy sets:

quantity = (very small, small, medium, large, very large)

Each member of the fuzzy set represents a factor designed to alter the food's relative

nutritional content based upon serving size. The translation formulas for each member of the fuzz set are shown in Table 2.

```
very small  = <nutrient content> * 0.50
small       = <nutrient content> * 0.75
medium      = <nutrient content> * 1.00
large       = <nutrient content> * 1.25
very large  = <nutrient content> * 1.50
```

Table 2. Fuzzy set formulas

Once all of the 'dayfood' items have been entered, the 'dayfood' facts are matched agains the database of known foods. All of the calories, vitamins, and minerals of the entered foods are totaled and used to generate a fact containing the individual's total nutritional intake for that day This 'total' nutritional fact is then asserted into the database in the form:

(total <calories> <calcium> <iodine> <iron> <magnesium> <phosphorus> <sodium> <vitamin A> <vitamin B1> <vitamin B2> <vitamin B6> <vitamin B12> <folic acid> <niacin> <vitamin C> <vitamin D> <vitamin E>).

If a 'dayfood' fact does not match an already existing food item in the database, NAES will ask the user if the food item should be asserted into the permanent database of food items. This particular feature of the expert system is very important because it achieves a flexible methodology whereby the ability to 'learn' and improve performance is realized.

Once the new food is asserted, it becomes part of the system's working knowledge base. The nutritional content of the new food item is also added to the 'total' food intake fact so that the complete dietary intake for that day can be used to correlate the nutritional deficiencies with the individual's daily eating habits.

Next, the system determines the person's specific USRDA nutritional group by matching personal data against the database. The system will place the user in one of fifteen different categories based upon age and sex. The nutritional content of the entered food items is compared with the USRDA guidelines for that specific person. The system then generates another fact called 'deficiencies'. It is of the form:

(deficiencies <calories> <calcium> <iodine> <iron> <magnesium> <phosphorus> <sodium> <vitamin A> <vitamin B1> <vitamin B2> <vitamin B6> <vitamin B12> <folic acid> <niacin> <vitamin C> <vitamin D> <vitamin E>).

The system then informs the user of any deficiencies in his or her diet citing the calculated deficiency percentages. The deficient nutrient(s) and their respective deficiencies are then asserted into the database in the form:

(def <nutrient> <amount deficient>).

This information is important because it can answer important health questions such as:

(a) Am I consuming too many calories?
(b) Do I consume appropriate amounts of all the essential nutrients?
(c) What nutrients are lacking in my normal diet?

Table 3 shows a sample run of menu option three, 'Dietary Analysis of Meal(s), by an individual with dietary habits that are less than exemplary.

```
Please enter your name:  Scott
Please enter your age:  24
Please enter your gender (m/f):  m

Quantities are: [very smalllsmalllmediumllargelvery large]

Enter breakfast meat group
Enter breakfast dairy product
Enter breakfast fruit and vegetable group
Enter breakfast bread and cereal group

Enter lunch meat group
Enter lunch dairy product
Enter lunch fruit and vegetable group
Enter lunch bread and cereal group

Enter dinner meat group  beef
Enter Quantity of "beef"  small
Enter dinner dairy product
Enter dinner fruit and vegetable group  peas
Enter Quantity of "peas"  very small
Enter dinner bread and cereal group

The following is a list of your USRDA Deficiencies (%):

55.97      Calories
94.13      Calcium
100.00     Iodine
68.5       Magnesium
35.19      Phosphorus
93.79      Sodium
91.28      Vitamin A
74.38      Vitamin B1
52.00      Vitamin B2
25.00      Vitamin B6
100.00     Vitamin B12
86.87      Folic Acid
9.84       Niacin
85.55      Vitamin C
100.00     Vitamin D
97.00      Vitamin E
```

Table 3. A run of 'Dietary Analysis of Meal(s)'

These deficiencies are utilized by the third major component of this system, the 'Ailment Prediction Based on Nutritional Deficiencies' menu option. Select this option if you are interested in speculating about possible ailments that you may incur based upon the continuation of your observed dietary habits. The knowledge base for this predictive analysis option was derived from the 'Nutrition Almanac' (Kirschmann 1975). This reference notes the fact that nutritional

authorities have linked deficiencies in one or more nutrients to the appearance of a number of diseases. Fortunately, most diseases caused by such deficiencies can be corrected when all essential nutrients are supplied.

This option can only be executed if you have previously run menu option two, 'Dietary Analysis of Meal(s)'. If you attempt to run menu option three, 'Ailment Prediction Based on Nutritional Deficiencies', without first running 'Dietary Analysis of Meal(s)', you will be directed to first run 'Dietary Analysis of Meal(s)'. Assuming that you have previously run 'Dietary Analysis of Meal(s)', selecting menu option three, 'Ailment Prediction Based on Nutritional Deficiencies', will automatically generate a list of zero or more possible ailments that you may incur if you continue to maintain such dietary habits. Using the dietary information entered in menu option two, and selecting menu option three we discover that this particular individual runs the risk of contracting several diseases if he continues to maintain his observed dietary habits.

Ailment: common cold
Rating: quite possible
% Deficient: Vitamin A   91.28 %
                Vitamin B6   25.00 %
                Vitamin C   85.55 %
                Vitamin D   100.00 %

Ailment: rickets
Rating: quite possible
% Deficient: Vitamin D   100.00 %
                Calcium   94.13 %
                Phosphorus   35.19 %

Ailment: scurvy
Rating: quite possible
% Deficient: Vitamin C   85.55 %

Ailment: pellagra
Rating: possible
% Deficient: Vitamin B1   74.38 %
                Vitamin B2   52.00 %
                Niacin   9.84 %

Table 4. A run of 'Ailment Prediction Based on Nutritional Deficiencies'

Table 4 is a sample run of menu option three, 'Ailment Prediction Based on Nutritional Deficiencies'. Listed along with the possible ailments are the fuzzy ratings and percentage deficiencies justifying the possible ailment rating.

This feature works quite efficiently due to the fact that each ailment is a rule. The left hand side of each ailment rule consists of nutrients that, if known to be consistently deficient in a person's diet, may have a causal relationship with the given ailment. These deficiencies are asserted into the knowledge base by running menu option two, 'Dietary Analysis of Meal(s)'. If all of the nutritional deficiencies are present, the ailment rule fires.

The fuzzy rating explanation facility is based upon the average nutritional percentage deficiencies that were calculated in the 'Dietary Analysis of Meal(s)' feature. Ratings are assigned as shown in Table 5.

Average % Deficient	Fuzzy Rating
0 - 25	Slightly Possible
26 - 50	Possible
51 - 75	Fairly Possible
76 - 100	Quite Possible

Table 5. Fuzzy ratings

Menu option four, 'top-ten', generates a top-ten listing of food items for a given nutrient. When you select this feature you will be presented with a seventeen item list (calories and sixteen other key nutrients) from which you are to select one item.

Once you have selected the item of interest, a "Working..." status message will appear. Shortly thereafter, an ordered list of the top-ten foods for that particular nutrient will be displayed on the screen. Table six is a sample run of this menu option.

Vitamin C (mg)	
01 orange	90.00
02 baked potato	20.00
03 banana	15.00
04 peas	13.00
05 corn flakes	8.80
06 pot pie	6.81
07 apple	5.20
08 eggnog	3.00
09 whole milk	2.44
10 apple pie	1.35

Table 6. A run of 'Top Ten'

Implementation of this feature was complicated by the need for a sorting algorithm. Once the user selects the nutrient of interest, the relevant index of the food item facts is known because, by design, there is a direct mapping between the list selection numbers and the food item template nutrition fields. A list is built consisting of all of the pertinent food item nutrient field values.

Next, the numbers are recursively compared in pairs. Beginning at the head of the list, the smaller of the two numbers is removed to another temporary list while the larger of the two remains in the original list. This process is repeated until finally only one number remains in the original list, and that number is the largest number of the original list. That largest number is then asserted into a new 'max' list.

This process is repeated ten times, each iteration using a new list that did not include the previously identified and removed maximum value. Finally, an ordered max list of the top-ten highest numbers is created and then used to match against the database of food item facts. These top-ten food items are then displayed in order on the screen along with their respective nutrient percentages.

Menu option five, 'Database Update', provides the user with a convenient mechanism for updating the database of food item facts. When you select this feature you may either:

(a) add a food item to the database;
(b) retract a food item from the database.

In order to add a food item to the database, you must be able to supply the necessary nutritional details for that food item. To retract a food item, you need only know the name of the food item.

This feature is important because it makes the system flexible. The scope of the pristine database can easily be expanded and thereby improve overall performance. Also, database errors are also easily corrected through the retract and add options.

Implementation of this useful feature was simple and direct. To add a food item fact to the database, the user-supplied information is simply asserted using the food item template. To retract a given food item, a match and retract is performed using the food item name. Table 7 shows a sample run for this feature.

```
How would you like to modify the data base?
  1. Add a food item
  2. Retract a food item

Please select 1 or 2:  2

Enter food name:  plum

"plum" has been retracted from the database.
```

Table 7. A run of 'Database Update'

The final menu option is 'Exit'. Select this option only if you want to exit from the Nutrition Advisor Expert System and be returned to the CLIPS' prompt. If you select this option inadvertently, simply type '(reset)' <RETURN>, and '(run)' <RETURN>. This will restart NAES.

Implementation of the exit feature is accomplished quite simply through the system clear screen and halt commands.

FINAL REMARKS

The CLIPS expert system shell provided an excellent developmental environment for the exploration of automated knowledge-based reasoning in the application area of dietary analysis and nutritional guidance. The forward-chaining rule-based language provided inferencing and representation capabilities that allowed the programmers to create the code of the system with a very application-oriented architecture. Facts and rules in the knowledge base could easily be understood because their names directly related the functionality of the rule to the user. The built-in inference engine eliminated the need for the programmer to create any kind of a reasoning mechanism. Additional information can easily be added to the expert system by creating new rules and adding more facts. Through the use of familiar terms in the facts and rules and the elimination of building an inference engine, the CLIPS expert system shell allows a developer to create a full-blown expert system for practically any application in a relatively short period of time.

REFERENCES

Giarratano, J. and Riley, G. (1989). Expert Systems: Principles and Programming, PWS-KENT Publishing Company, pp. 8-9.

Kirschmann, J. (1975). Nutrition Almanac, McGraw-Hill Publishing Company, pp. 108 - 166, 185 - 220.