An artificial intelligence system for computer-assisted menu planning

GRACE J. PETOT, MS, RD; CYNTHIA MARLING, PhD; LEON STERLING, PhD

ABSTRACT

Planning nutritious and appetizing menus is a complex task that researchers have tried to computerize since the early 1960s. We have attempted to facilitate computer-assisted menu planning by modeling the reasoning an expert dietitian uses to plan menus. Two independent expert systems were built, each designed to plan a daily menu meeting the nutrition needs and personal preferences of an individual client. One system modeled rule-based, or logical, reasoning, whereas the other modeled case-based, or experiential, reasoning. The 2 systems were evaluated and their strengths and weaknesses identified. A hybrid system was built, combining the best of both systems. The hybrid system represents an important step forward because it plans daily menus in accordance with a person's needs and preferences; the Reference Daily Intakes; the Dietary Guidelines for Americans; and accepted aesthetic standards for color, texture, temperature, taste, and variety. Additional work to expand the system's scope and to enhance the user interface will be needed to make it a practical tool. Our system framework could be applied to special-purpose menu planning for patients in medical settings or adapted for institutional use. We conclude that an artificial intelligence approach has practical use for computer-assisted menu planning. *J Am Diet Assoc. 1998;98:1009-1014.*

For more than 30 years, the goal of planning menus by computer has been an elusive one. In 1964, Balintfy (1) used linear programming to optimize a menu for nutritional adequacy, cost, and consumer satisfaction. In 1967, Eckstein (2) rejected this mathematical approach in favor of a "random" approach. She composed dinner menus of randomly selected food items and evaluated their cost, color, texture, shape, energy content, variety, and acceptability. She was optimistic about the prospects for her system, noting that 99 menus could be planned in 90 seconds, but warned that expansion and refinement were needed.

Thirty years later, computer-assisted menu planning is still not widely used (3). Human experts consistently outperform computers at this difficult task, which Eckstein characterized as an art and a science (4). The field of computer science that specializes in problems more readily solved by people than by computers is artificial intelligence (5). An artificial intelligence system that attempts to model the processes a human expert uses to perform a difficult task is called an expert system. Different types of expert systems model different kinds of expertise. A rule-based expert system formalizes the rules an expert follows in performing a task, such as planning a menu. A case-based expert system represents past experiences an expert has had, such as previously planned menus (6). In the past decade, both case-based and rule-based expert systems for menu planning have been built (7-9).

G. J. Petot is an assistant professor emerita in the departments of Nutrition and Epidemiology and Biostatistics in the School of Medicine, Case Western Reserve University, Cleveland, Ohio. C. Marling is an assistant professor in the School of Electrical Engineering and Computer Science at Ohio University, Athens; at the time of the study she was a doctoral student in the Department of Computer Engineering and Science at Case Western Reserve University.
L. Sterling heads the Department of Computer Science at the University of Melbourne, Parkville, Victoria, Australia; at the time of this study, he was a professor in the Department of Computer Engineering and Science, Case Western Reserve University.
Address correspondence to: Cynthia Marling, PhD, School of Electrical Engineering and Computer Science, Morton 416, Ohio University, Athens, OH 45701.
Address reprint requests to: Grace J. Petot, MS, RD, Department of Nutrition, School of Medicine, Case Western Reserve University, 10900 Euclid Ave, Cleveland, OH 44106.

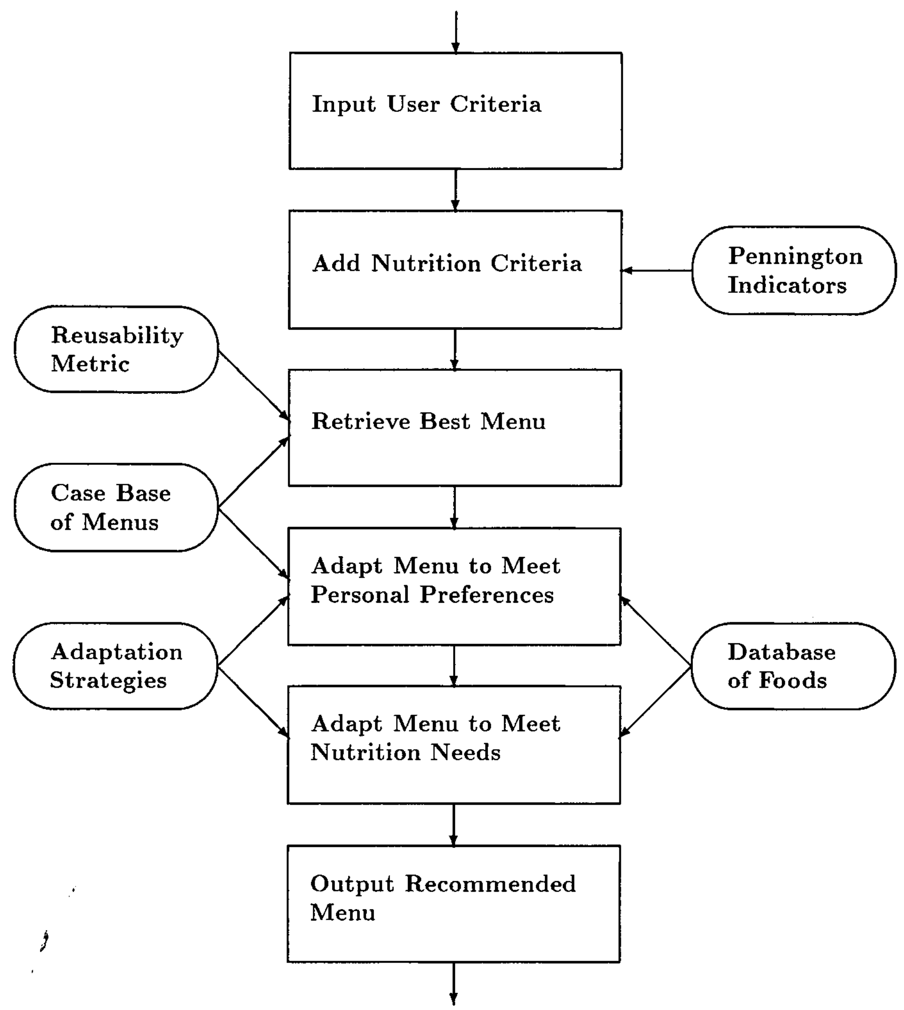


FIG 1. A flow chart for the CAse-based Menu Planner.

Our research furthers the goal of computer-assisted menu planning by combining the strengths of case-based and rule-based reasoning into a single system. Our objective was not only to build a better menu planner, but also to better understand and model the thought processes that make menu planning so challenging.

MENU PLANNING SYSTEMS

Building any expert system is a collaborative effort between an expert and a "knowledge engineer." The expert explains the thought processes used to perform some task, and the knowledge engineer models these processes in a computer program. Together, they review the program, refining and validating it, iterating as they learn more about the nature of the task.

We built 2 expert systems, the CAse-based Menu Planner (CAMP)[1] (10) and the rule-based Pattern Regulator for the Intelligent Selection of Menus (PRISM) (11). Each system is intended for use by a dietitian in consultation with a client. A dietitian would use the system to assist clients who must learn to adjust their diet to reduce energy intake or control specific nutrient content. Personal preference criteria are included to ensure that the client willingly accepts the foods on the menu. Both systems meet numeric constraints, including nutrient minimums and maximums, and aesthetic goals to plan a daily menu meeting the client's needs. To focus on the most critical aspects of menu planning, simplifying assumptions are made; considerations of cost, ingredient availability, and cooking skill are omitted. The system assumes that the client is a healthy adult.

Each of our expert systems models a different type of reasoning a dietitian might use to plan menus. A dietitian may think in an experiential, or case-based way, considering past menus as the basis for new menus. For example, the American Heart Association's Hearty School Lunch Menus (12) provide more than 100 sample menus, plus guidelines for adapting them to the needs of particular schools. Alternatively, a dietitian might use rules to plan a menu. For example, 1 rule might be to plan the dinner entree first, and then to plan the lunch entree, avoiding those foods used for dinner. Such rules are found in instructional texts (3). Other rules guide which foods

[1]Balintfy first used this acronym in 1964 to stand for Computer Assisted Menu Planning.

go together, like roast turkey with stuffing, or which foods should not, like roast turkey with ketchup.

We evaluated, compared, and contrasted our case-based CAMP system and our rule-based PRISM system to identify their strengths and weaknesses. The best of both systems was combined in a hybrid system, CAMP Enhanced by Rules (CAMPER), which improves on both preliminary systems and represents a step forward toward the goal of computer-assisted menu planning.

The CAse-based Menu Planner

CAMP operates by storing, retrieving, and adapting daily menus as shown in Figure 1. A client's energy intake level and optional preference criteria are entered first. Nutrition criteria are added to ensure that the Reference Daily Intakes (RDIs) (13) are met. A minimal set of indicator nutrients based on Pennington's work (14) is used for this purpose.

The menu best suiting the criteria is retrieved from CAMP's case base of 84 menus. Menus were obtained from reputable sources (15-17) and modified as needed to ensure that they satisfy the RDIs, Dietary Guidelines for Americans (18), and aesthetic standards. The best case is selected using a reusability metric, which checks each case against all constraints. Any case meeting all constraints constitutes an exact match and is retrieved. Unlike in database applications, exact matches are rare. It would be infeasible to store in advance menus meeting all conceivable needs. Constraint violations are assigned penalty scores based on how difficult they are to fix. CAMP finds the case that is easiest to adapt, striking a balance between the number and severity of constraint violations. This case serves as a starting point.

The retrieved case is adapted to meet any unmet constraints. The adaptation framework, based on an expert approach to adapting menus, is shown in Figure 2. For adaptations like adding snacks or changing meal types, parts of other menus that are close matches are used. Nutrient-specific deficiencies are corrected using adaptation rules. A database of foods, derived from the US Department of Agriculture Survey Nutrient Data Base Release 7 (USDA Nutrient Data Base for National Food Surveys [database online], version 7, 1990, US Dept of Agriculture, Agricultural Research Service; available at: http://www.nal.usda.gov/fnic/food/foodcomp) and the Highland View Hospital-Case Western Reserve University Nutrient Data Base (HVH-CWRU Nutrient Database, version 11, 1991, Department of Nutrition, Case Western Reserve University, Cleveland, Ohio), is used to calculate the nutrient effects. The adapted case becomes the system output. A sample input screen is shown in Figure 3. Figure 4 shows the menu and analysis produced for the sample input. A demonstration version of CAMP is available on the World Wide Web at: <http://pearson.cwru.edu/camp>.

- Check the number of snacks. Adjust, if necessary.
- Check meal types. Swap meals to accommodate preferences, if necessary.
- Eliminate any forbidden food items.
- Check energy level. Adjust serving sizes, if necessary.
- Fix any nutrient-specific deficiencies.

FIG 2. The menu adaptation framework of the CAse-based Menu Planner.

The Pattern Regulator for the Intelligent Selection of Menus

PRISM uses rules to generate menus (11). It relies on a wide variety of menu and meal patterns. A daily menu follows this pattern: breakfast, optional snack, lunch, optional snack, dinner, optional snack. Each meal in the menu can fit any of a number of different patterns. To generate a menu, PRISM successively refines patterns, filling general pattern slots with specific foods. For example, if a dinner pattern calls for a meat, a starchy food, and a vegetable, this could be refined to beef, potatoes, and a green vegetable. Then this could be further refined to roast beef, mashed potatoes, and steamed broccoli.

PRISM was constructed using a network of 4 layered databases as shown in Figure 5. At the bottom layer are 1,200 individual food items. These are the building blocks from which menus are constructed. Portion-size information and nutrient data for each food are maintained, as in CAMP. But whereas CAMP derives the context for each food from a past menu, PRISM establishes the allowable contexts by means of 3 other databases and arcs denoting relationships between database entries. Figure 5 shows that an egg breakfast is a hearty breakfast. It includes an egg dish and a bread dish, and may include a breakfast meat dish. A bread dish includes a bread food and may include a bread spread. For example, rye bread is a loaf bread, which is a bread food, and butter is a bread spread. So, rye bread with butter may be part of an egg breakfast.

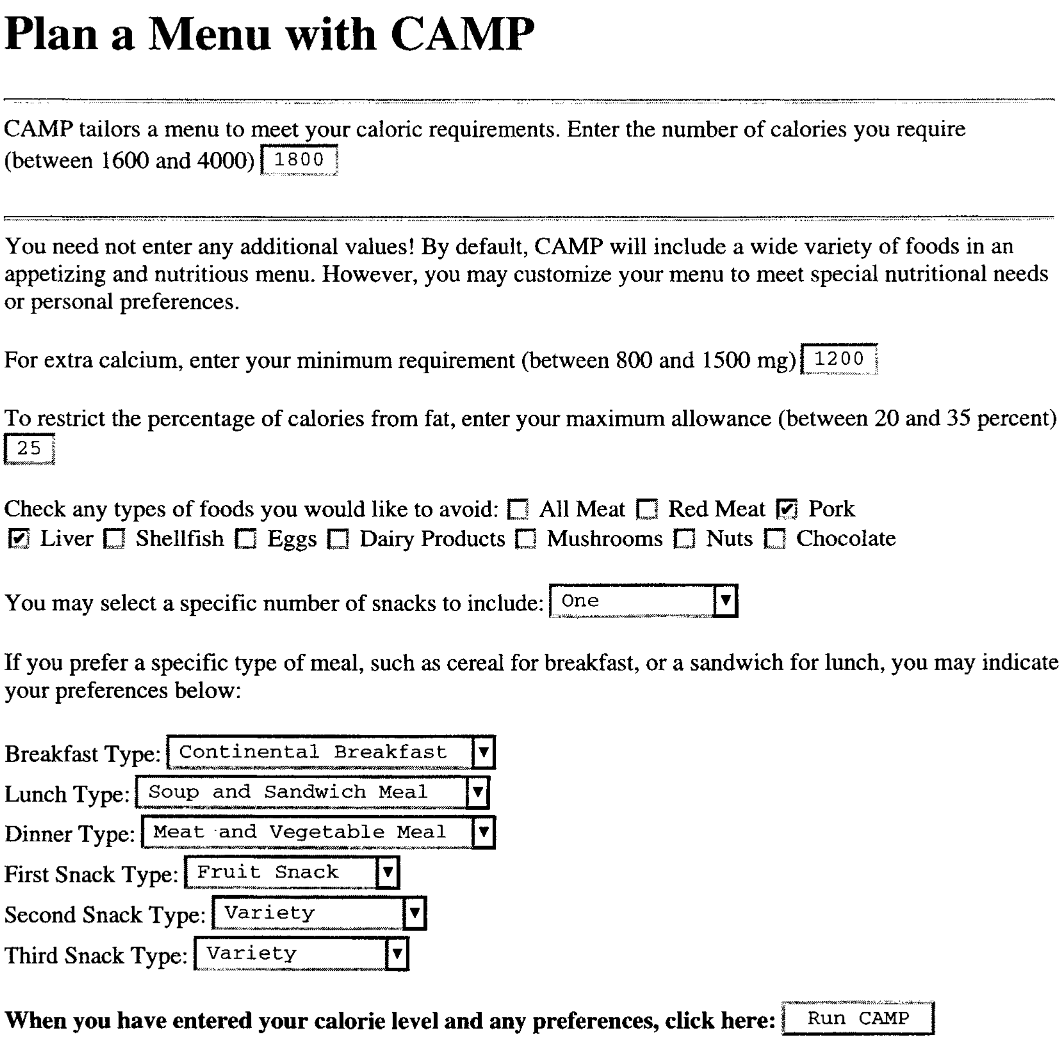
Generated menus are checked against nutrition constraints. Menus seldom meet all constraints initially, so they are repaired. PRISM backtracks when a menu is low in some nutrient, replacing some foods with others containing more of that nutrient. Unfortunately, this strategy is not entirely effective. PRISM's menus meet expectations as to menu form, but do not always meet all nutrition constraints. Next, PRISM displays the menu and allows the user to conduct a "what if" analysis, adding or deleting foods, and seeing the effects on nutrient content. This allows greater customization to individual tastes, and provides an educational tool for learning the effects of food choice on nutrition.

SYSTEM EVALUATION

CAMP and PRISM were evaluated by running them on a wide variety of test cases designed to produce different kinds of menus. Over repeated trials, outputs were reviewed and problems were corrected as they were identified. For CAMP, this meant adding new cases to include more types of menus. For PRISM, this meant adding or refining rules. Next, feedback was solicited from practicing dietitians and nutrition students. Both systems were judged to produce useful menus, but they were found to have different strengths and weaknesses.

CAMP's biggest advantage is its ability to find and then modify a menu that meets nearly all constraints. PRISM builds a menu from scratch, 1 step at a time, but it can only evaluate a fully planned menu. This delayed evaluation forces a need to backtrack and repair menus. Because repairing one problem may create another, PRISM can satisfy fewer constraints at once than CAMP can.

PRISM's biggest advantage is its creative flair. With more than 1,200 foods in its database, its "what if" analysis capability allows users to propose and evaluate creative food combinations. "What if" analysis is a useful thinking process not easily supported by case-based reasoning, which instead emphasizes "what did happen." Although research in extending case-based reasoning to support creative design is underway, case-based reasoning systems are presently good at reusing old solutions, not at considering new possibilities (19).



Plan a Menu with CAMP

CAMP tailors a menu to meet your caloric requirements. Enter the number of calories you require (between 1600 and 4000) [1800]

You need not enter any additional values! By default, CAMP will include a wide variety of foods in an appetizing and nutritious menu. However, you may customize your menu to meet special nutritional needs or personal preferences.

For extra calcium, enter your minimum requirement (between 800 and 1500 mg) [1200]

To restrict the percentage of calories from fat, enter your maximum allowance (between 20 and 35 percent) [25]

Check any types of foods you would like to avoid: ☐ All Meat ☐ Red Meat ☑ Pork ☑ Liver ☐ Shellfish ☐ Eggs ☐ Dairy Products ☐ Mushrooms ☐ Nuts ☐ Chocolate

You may select a specific number of snacks to include: [One ▾]

If you prefer a specific type of meal, such as cereal for breakfast, or a sandwich for lunch, you may indicate your preferences below:

Breakfast Type: [Continental Breakfast ▾]
Lunch Type: [Soup and Sandwich Meal ▾]
Dinner Type: [Meat and Vegetable Meal ▾]
First Snack Type: [Fruit Snack ▾]
Second Snack Type: [Variety ▾]
Third Snack Type: [Variety ▾]

When you have entered your calorie level and any preferences, click here: [Run CAMP]

FIG 3. Sample input screen for the CAse-based Menu Planner (CAMP).

THE HYBRID SYSTEM

The hybrid system CAMPER combines CAMP's ability to satisfy nutrition constraints with PRISM's creativity. The system was built by expanding CAMP with rule-based enhancements from PRISM. These enhancements augment CAMP with a "what if" analysis module and a larger, more versatile, database.

CAMPER's database includes more food items than CAMP's and allows the food items to be used in different ways. With CAMP, a food item is viewed only in context within a case. Its database is never queried to find menu items. But this is not so for PRISM; the ability to configure multiple food items in multiple ways allows PRISM to create a broader variety of menus than CAMP can produce. Therefore, supplemental files were built for CAMPER to describe the different roles each food item can fulfill.

With CAMPER, the user may ask to add, delete, or replace foods in the recommended menu. When the user asks to replace a food, CAMPER presents a choice of alternative foods that could reasonably fulfill the same role. When a user wants to replace a dessert, for example, he or she may choose from ice creams, pastries, or fancy fruits, but not from bread spreads, beverage accompaniments, or sandwich fillings. This allows the intelligence already built into the system to assist the user with interactive menu modification.

A customized menu may be saved in the case base, allowing CAMPER to improve its menu planning capabilities. This feature was not part of CAMP or PRISM, but was made possible by the synergy between them.

CAMPER was programmed in C and runs under UNIX on a Sun SPARCserver 1000E (Sun Microsystems, Palo Alto, Calif). Additional effort will be required to build a practical personal computer–based tool that expands the system's scope and provides a robust user interface.

MENU PLANNING CHALLENGES

We have been investigating the use of artificial intelligence for menu planning since 1988. Our first system, the Expert System

CAMP's Recommended Menu

Breakfast
¾ c pineapple chunks, packed in juice
2 English muffins with
2 tsp margarine
1 c skim milk

Lunch
Sandwich
- 1 slice whole wheat bread
- 2 oz chicken breast
- 1 leaf lettuce
- 1 slice tomato
- 1 tsp mayonnaise-type salad dressing

1 c vegetable soup
6 saltine crackers
1 ½ medium oranges
1 c skim milk

Dinner
Salad
- 1 c mixed salad greens
- ½ medium tomato, sliced
- 1 Tbsp Italian dressing

3 oz roast leg of lamb
¾ c spinach
1 medium baked potato
1 tsp margarine
½ c corn
Coffee, tea, or water

Snack 1
¼ c raisins

Nutritional Profile[a]
Energy: 1,830 kcal
Percentage of energy from fat: 23
Percentage of energy from protein: 19
Percentage of energy from carbohydrate: 61
Percentage of energy from alcohol: 0

Percentages of Reference Daily Intakes (RDIs)[b]

Protein: 173%	Vitamin C: 333%	Thiamin: 134%
Niacin: 137%	Riboflavin: 135%	Vitamin B-6: 124%
Vitamin B-12: 71%	Folic acid: 146%	Vitamin A: 369%
Vitamin E: 36%	Iron: 108%	Calcium: 123%
Phosphorus: 140%	Potassium: 132%	Magnesium: 113%
Copper: 102%	Zinc: 72%	

Nutrient Data

Energy: 1,830 kcal	Protein: 86.3 g	Fat: 47.6 g
Carbohydrate: 278 g	Alcohol: 0.0 g	Fiber: 26.7 g
Cholesterol: 131 mg	Vitamin C: 199.60 mg	Thiamin: 2.01 mg
Niacin: 27.42 mg	Riboflavin: 2.29 mg	Vitamin B-6: 2,471 μg
Vitamin B-12: 4.27 μg	Folic acid: 0.59 μg	Vitamin A: 18,455 IU
Vitamin E: 7.26 mg	Iron: 19.44 mg	Calcium: 1,229 mg
Phosphorus: 1,398 mg	Sodium: 2,230 mg	Potassium: 4,617 mg
Magnesium: 453 mg	Copper: 2.03 mg	Zinc: 10.86 mg

FIG 4. The CAse-based Menu Planner's menu and analysis for the input shown in Figure 3.
[a]The standard method of calculation does not ensure that percentages add to 100.
[b]The RDI for Vitamin B-12 is 6 μg, which is higher than other standards. See reference 13.

on Menu Planning, planned menus for patients on a severely restricted low-protein diet (7). Since then, we have gained insight into the nature of the task of computerized menu planning and what makes it so challenging. Part of the problem appears to be the common sense involved. There's a sense that meals appeal to people, and computers do not share this sense. Representing common sense in computers still challenges artificial intelligence researchers. Also, there are cultural expectations as to the proper form of a menu. Our Expert System on Menu Planning implementor was from China and seldom ate Western-style meals. The Expert System on Menu Planning ably met nutrition goals, but sometimes produced odd combinations, such as hot chili sauce with a grapefruit-flavored breakfast drink. Our implementor lacked the cultural awareness that this was distasteful, and computers lack this awareness, too. Finally, many constraints must be met, and some constraints interfere with others. If a client wants an egg breakfast, the cholesterol maximum may be exceeded. This problem is not limited to computer-assisted menu planning. Dollahite et al (20) have reported that limiting red meat to meet the Dietary Guidelines for Americans makes it difficult to meet the zinc requirement.

Using cases simplifies the menu planning task, because the common sense of an expert dietitian is already implicit in each stored menu. It is easier to begin with a retrieved menu than to begin planning from scratch. Before our work, cases were used

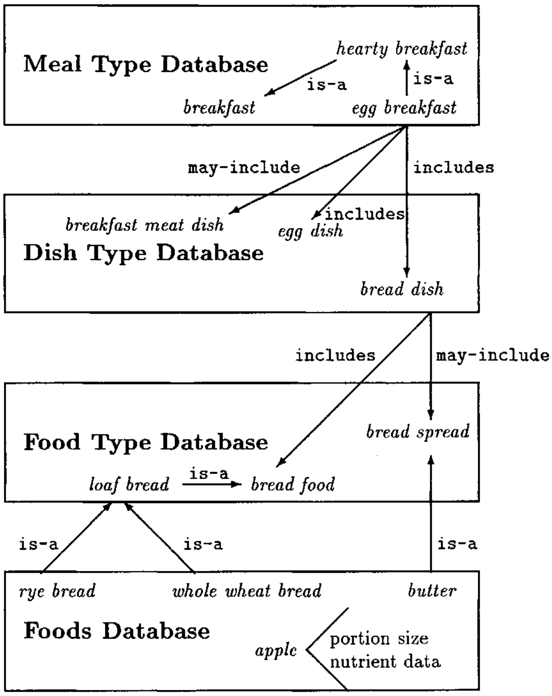


FIG 5. The Pattern Regulator for the Intelligent Selection of Menus' layered databases.

to advantage in a system called JULIA, which plans dinner party menus (8). More recently, the usefulness of cases in cognition has been clarified (21), and the health care field has been recognized as one that especially benefits from case-based reasoning (22).

One aspect of our work that would be useful in other menu planning applications is our serving-size adjustment technique. Serving-size information is most often omitted from published menus, even though precise quantities are needed for nutritional analysis. To accommodate varying serving sizes, we added small, medium, and large serving sizes to the entry for each food in our database. When CAMPER adjusts the caloric level of a menu, it consults the database to select the best serving size for each food item. Scaling algorithms ensure that food portions are adjusted in the order a dietitian would adjust them.

APPLICATIONS

CAMPER is a tool for planning daily menus in accordance with the nutrition needs and personal preferences of individual clients. Although the present version of CAMPER plans menus for healthy adults, the framework and methodology could also apply to planning special-purpose menus for use in many different settings. For example, preplanned menus for metabolic diets in a clinical research center can become a case base, which can then be accessed for menus. Menus revised to meet specific research needs can be added to the case base for future protocols. A menu planner for diabetic diets could be built by tuning the adaptation strategies to meet individual needs.

The system could be adapted for use by institutions such as nursing homes, hospitals, schools and colleges, wellness and fitness centers, and nutrition education programs. For each application, a case base of menus could be established for designing menus to meet seasonal changes, dietary prescriptions, special events, or specific age groups.

Initial costs would be involved in creating a case base of menus that meets the application's requirements, selecting a nutrient database that includes all foods and recipes used in the menus, and fine-tuning adaptation strategies. New, revised menus may be added to the case base as they are created. Depending on the setting and application, cost savings may be achieved as the system is used over time. ■

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