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The application and performance of a generic task routine decision making algorithm to recipe selection in meal planning

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THE APPLICATION AND PERFORMANCE OF A GENERIC TASK ROUTINE DECISION MAKING ALGORITHM TO RECIPE SELECTION IN MEAL PLANNING

A Thesis

by

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THE APPLICATION AND PERFORMANCE OF A GENERIC TASK ROUTINE DECISION MAKING ALGORITHM TO RECIPE SELECTION IN MEAL PLANNING

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A nutritional meal planning system was implemented to test the effectiveness of a previously developed routine decision making algorithm. The combinatorics involved in ordering recipes in all possible combinations to produce variability in a meal plan and provide sufficient nutrition is conceptually intensive. Meal planning involves selection of food to eat to fulfill a person's nutritional and personal preferences. This thesis demonstrates meal planning as a decision making problem and demonstrates the utility of the routine decision making algorithm by solving this problem. Generic Tasks, identified through artificial intelligence research, provides the basis for this algorithm. It uses user preferences and to select recipes from a database of possible recipes and generate meal plans for the user.

DEDICATION

To Shine-

A soft whisper of encouragement, a gentle nudge to forge ahead, a tender kiss to say "I Love You"... for all this and more, you have my eternal love and gratitude. I couldn't have done it without you. The hard part is over, now our life together begins.

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INTRODUCTION

1.1 Expert Systems

An expert system is a system that contains "expert" knowledge. This knowledge is used to solve problems within the domain of that knowledge such as diagnosis, planning or advice giving. A knowledge-based system is one that is similar to an expert system, but does not rely on expert knowledge. Instead, it bases decisions on a knowledge base that is composed of common knowledge that many people would have. There is much overlap between these two types of systems since knowledge that is considered expertise for most people is familiar and routine knowledge for an expert in that field. For many years, researchers in the field of artificial intelligence (AI) have implemented and experimented with these types of systems. Many systems have been created to solve diagnosis and planning problems using some form of a knowledge base. For instance, MYCIN was created to diagnose and suggest treatment for blood infections using expert knowledge in the form of rules (Shortliffe, 1976). R1 (commercially known as XCON) was implemented to configure VAX computer systems also using rules for knowledge (McDermott, 1982).

While many successful systems have been designed in similar ways, they have lacked the versatility to solve a variety of problem types. For example, after MYCIN was developed, EMYCIN was created for the purpose of implementing additional diagnostic systems (McDermott, 1982). EMYCIN was the MYCIN system without the domain specific information. This shell could then be used for implementing other diagnostic systems. A problem was that a system implemented using EMYCIN was based on rules, isolating it to diagnostic type problems. Compiling rules is difficult for a large knowledge base. It is easy to overlook rules or parts of rules that will cause problems within the system when a decision is being concluded. Missing information could cause false conclusions. Inconsistent knowledge also leads to false conclusions

In the late 1970's researchers at Ohio State began work on the MDX medical diagnostic system. Implementation of this system introduced the idea of decision making as a classificatory problem which eventually led to the theory of Generic Tasks (Chandrasekaran, 1986). The Generic Task approach provides a means for creating wide-ranging solutions to a variety of problem types. Specifically, classification has been identified as a major task within disparate problems.

The *Encyclopedia of the Library of Information and Science* was used in reference to style and format of this thesis.

Planning and decision making are two related types of construction problems that have been studied in the field of Artificial Intelligence. Planning is the process of taking choices and sub-choices related to a particular problem, and *ordering* them in some efficient and effective manner in order to solve some stated problem. Decision making is the *selection* of those choices and sub-choices to fulfill an agents needs. Figure 1 shows the relationship between planning and decision making.

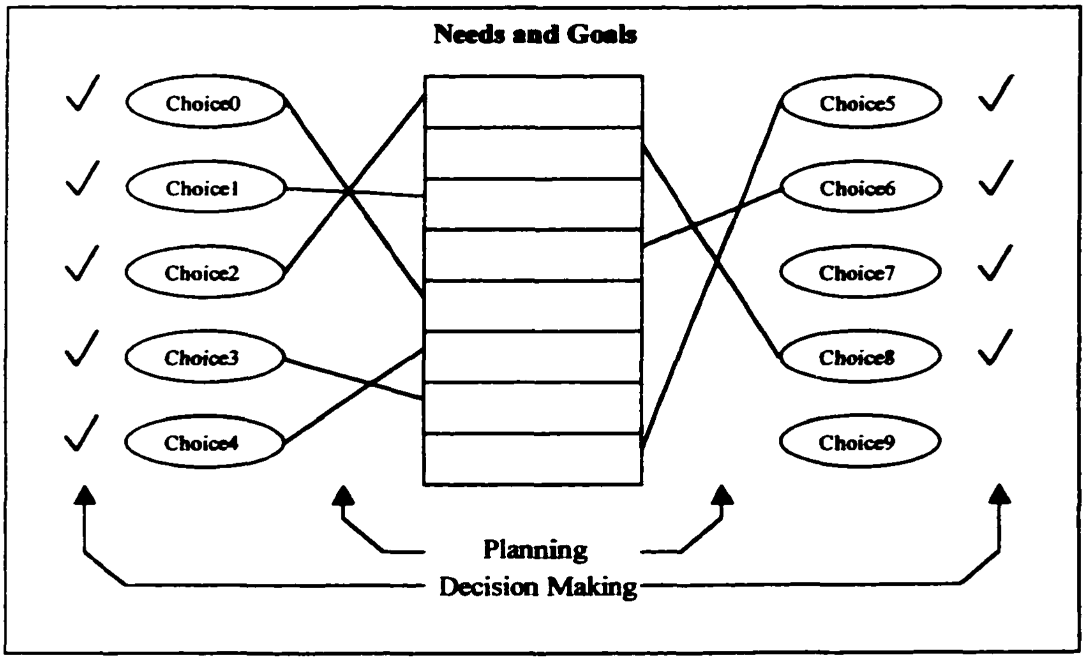

Figure 1 Planning vs. Decision Making

Particular choices are selected to fulfill the users needs through decision making. The act of ordering the selected choices to produce a final collection of choices that are in an order that will best fill the users needs is planning. A variation of decision making is routine decision making. A *routine* decision making situation is one where the problem has been solved many times before. The previous solutions are then available to apply to a new problem so that new decisions of the same type can be made.

The use of classification can be applied to decision making quite easily. Each possible choice in the space of domain solutions can be identified as a member of some broader abstract class. This class is comprised of all other choices that fall into the same classification level. For example, in medical diagnosis of a bacteriological infection, one classification might be set up to identify the bacterial cell shape, which is used for identification. Elements in this class might include rod, cocci or spiral. Most of the time one of these can be identified as the best choice so that the other choices can be discarded and the search can progress. Identification of one choice allows progression to a more specific classification level that will bring the solution one step closer and rule out solutions that are not possible based on the new classification. Here, classification is identified as a central component in decision making. Before elaborating, consider Generic Tasks.

1.2 Generic Tasks

Through the development of MDX, hierarchical classification was identified as a fundamental task in problem solving. Denoted as a Generic Task, it was the first of several identified. Generic Tasks are general abstractions of problem solving that can be applied to any problem that can be identified as a decision making problem. Six Generic Tasks have been identified as elements for implementation of a knowledge based system: Hierarchical Classification, Hypothesis Matching, Knowledge-Directed Information Passing, Object Synthesis by Plan Selection and Refinement, State Abstraction, and Abductive Assembly as described below (Chandrasekaran, 1986).

Hierarchical Classification is a process of searching a taxonomic hierarchy of domain concepts for those that apply to the given situation. It uses a hierarchy for the arrangement of the knowledge needed ordered by some appropriate generality (see Figure 2 below). Domain concepts or choices to be considered are arranged from general to specific. This process allows choices that are not useful to be discarded from the pool of possible solutions. Any choices dependent upon the choices that are eliminated are also discarded. This greatly reduces the number of choices that are to be considered as possible choices. Once a choice is established, refinement takes place to determine which other pieces of information are established.

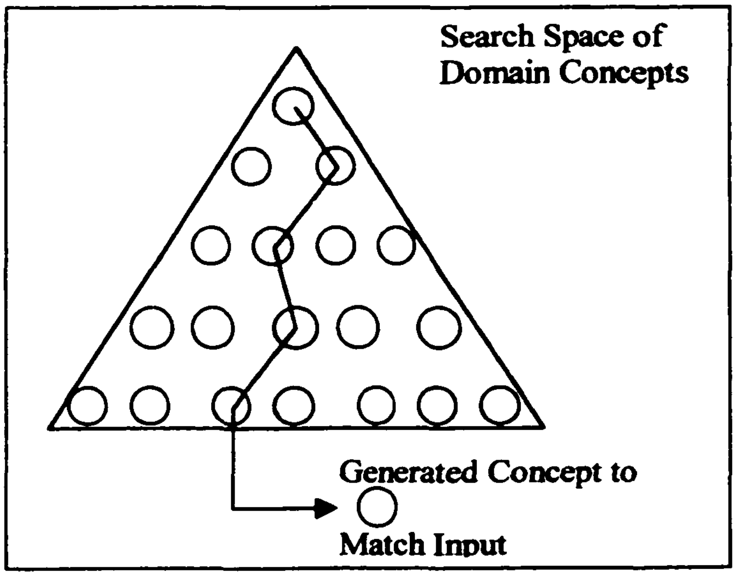

Figure 2 Concept Generation using Hierarchical Classification

Routine Recognition is a process that determines the relevance of a choice or the suitability of a concept when applied to the current situation. A recognition agent is a problem solver that determines if a specific choice is applicable to the current goal. The recognition agent contains the domain information required to identify if the particular choice is applicable. This task can be used during Hierarchical Classification to either establish or reject that choice as a possible solution to the problem.

Knowledge-Directed Information Passing refers to data inference. This is when knowledge can be inferred by a state already known to exist within the problem being. This type of "rule-based" knowledge is often used in expert systems. An object can be used to code information that might need to be established by the system through knowledge-directed information passing.

Object Synthesis by Plan Selection and Refinement is used in a routine design situation. This is a situation where the objects/components that the final solution will consist of are known. The plans to construct the product (solution) are also available. A component in the solution is selected. Available plans are considered and the best plan is selected. The plan generates the steps and variables required to design the component. This process is done recursively until a final product is completed.

State Abstraction is a way to incorporate cause and effect knowledge into a knowledge based system. Information about the functionality of the problem being solved is encoded so that when it is necessary to access a change in the system, the effect throughout the entire system can be calculated/evaluated.

Abductive Assembly is the process of taking possible solutions identified through other problem solving (e.g. Hierarchical Classification) and applying constraints to select and combine the choices that best explain the circumstances behind the data being examined. Choices left that cover multiple parts of the overall data are selected before those that only satisfy one requirement in the overall goal. At the completion of Abductive Assembly it is possible to implement an explanation of why particular choices were selected over others. This is used in systems that perform tasks such a diagnosis.

The researchers at Ohio State identified these tasks as important parts of problem solving and used them to develop expert/knowledge-based systems that solve problems in medical diagnosis, mechanical diagnosis, data interpretation, design and planning. Here decision making is the focus.

1.3 Generic Tasks and Decision Making

It has been suggested that decisions are composed of primitive components, that can be organized and arranged from a general to specific order [Fox, 1997]. If the decision components can be identified and organized into a general to specific fashion, a hierarchy can be used to represent the knowledge in a logical order so that Hierarchical Classification can then be used to generate possibly useful decisions over this domain. Routine Recognition can be used to evaluate each individual choice and determine how applicable it might be. A variation of Abductive Assembly, provides a way to unite the components selected by classification into a compound decision that fulfills all of the user's stated needs.

A generic routine decision making algorithm that can be proved to be efficiently applicable to any routine decision making task would be of great use to researchers and application software solving decision making problems. There are many problems that fall into the category of decision making and they cover many different domains. Since any of these decision making problems can be solved by applying a combination of Generic Tasks, an algorithm based on these tasks would be universal to all routine decision making problems.

Planning and scheduling problems fall under the category of decision making. Research has established solutions to individual problems in some of these areas, but has fallen short of finding a generic solution that could easily be applied to all decision making problems. The algorithm used here implements knowledge in a more natural and straightforward way than implementations using rules or cases. It is much easier to enumerate choices in the decision path by moving from the initial state at a very general starting point defining more specifically closer to the final state ending with the solution at the final state. If rules or cases are used, it is extremely easy to overlook vital information necessary for system functionality and accurate results. Also, through routine recognition, recognition agents can be created that easily and directly represent user supplied knowledge in the form of preferences and constraints. Once the knowledge base is implemented using the above mentioned algorithm, decisions can be made at each level of the hierarchy as to which path to follow. When routine decisions are being made, this step is easily implemented since previous solutions to the problem are known and tools used for those previous solutions can be called upon to help in the new solution. This algorithm has been successfully implemented in two systems:

Shopper-a consumer decision maker on the domain of grocery selection for the week based on a consumer's personal preferences and needs

Routine Scheduler-a scheduling program for scheduling instructors to teach classes based on the classes that need to be taught and the instructors' availabilities and preferences.

This thesis will introduce a third implementation of this algorithm in the domain of nutritional meal planning covering algorithm testing and comparison to different implementations of similar problems.

1.4 System Introduction

Another problem that is included in the category of decision making is nutritional meal planning. Nutritional meal planning is a complex decision making problem that is part of everyday life. This problem involves balancing both a persons needs and preferences while satisfying the user in both areas. Tradeoffs must be made between nutritional constraints and preferences and personal constraints and preferences to find a balance the user will be satisfied with [Cox and Fox, 2000; Fox and Cox, 2000a].

Nutritional constraints include special diets that the user has to follow possibly because of a medical condition such as diabetes or heart disease. These constraints might include following an American Diabetes Association Exchange Plan or limiting the total carbohydrate intake. Nutritional preferences would include limitations similar to constraints such as a limitation in the number of calories the user would like to consume in a day or the amount of total fat or sodium intake. The difference between constraints and preferences is that constraints are not flexible. They must be satisfied by the meal plans created. Preferences are also satisfied, but are more flexible when the meal plan is being created.

Personal constraints include food limitations such as if the user is allergic or intolerant to a certain food, or if the follow a restricted diet, for example a vegetarian. Personal preferences differ from personal constraints in that the preferences are more focused on individual taste. Preferences might include particular foods or recipes that the user likes or dislikes.

Meal Planner is the system that is the focus of this thesis. Its goal is to successfully create usable nutritional meal plans for a user taking into consideration both nutritional preferences and constraints and personal preferences and constraints as described above. This thesis introduces meal planning as a problem and presents it as an interesting problem applicable to artificial intelligence research. The implementation of this system demonstrates the usefulness of the algorithm mentioned in the last section to another knowledge domain.

CHAPTER II

LITERATURE REVIEW

2.1 Problem Solving Overview

Problem solving involves moving through a collection of states in order to find a solution to a given problem. Whether the problem is selecting moves in a chess game or manipulating a robot to perform certain actions, finding a solution for the desired goal can be challenging. Searching for a given solution can be done in many ways such as using heuristic based search such as best-first search, or hill-climbing techniques. When large problems are considered, the search space (and all possible choices within that space) becomes intractable to search through. Artificial intelligence researchers have spent a large amount of time and effort devising effective techniques for problem solving. Three of these techniques discussed here are general purpose Planning techniques, Case-Based Reasoning, and Generic Tasks. Through research and system implementation, these techniques have proved to be effective solutions to problem solving.

2.2 Planning

2.2.1 Planning Overview

Planning can be defined as the selection and ordering of sub-goals that will satisfy the goal sought. Planning problems often involve large search spaces that include all possible sub-goals that could be used to reach the final goal. Due to the many combinations that can be made between these sub-goals, this problem is intractable in which a search for a set of these sub-goals to achieve a final goal is concerned. In order to effectively solve this type of problem and be classified as a planning problem, the problem must be able to be decomposed into two different ways. It must be possible to break the problem down so that only the relevant information is considered and manipulated. This decreases the search space for the solution and makes it manageable. It must also be possible to break the problem down into smaller problems that can be individually solved and then combined to create the final problem solution. When a planning problem is decomposed in this way, it is easier to solve since smaller problems are easier to solve than bigger ones. It is also computationally less expensive since a smaller problem requires a smaller set of sub-goals that need to be considered to get a final resulting solution to that sub-problem. This type of approach to problem solving is dependent upon whether or not the problem can be decomposed in these two ways. If it cannot be decomposed, another technique must be used. Another constraint to this technique is whether or not the complete search space is known and can be bound. If the search space of sub-goals cannot be enumerated and bound within the system, a successful implementation of the problem cannot be achieved. There would be missing domain knowledge that is necessary for a solution to be found [Rich, 1991].

One classic domain in which planning can be applied is blocks world. Blocks world is a domain that contains a table, a robotic arm, and blocks. Operations are defined for manipulation of these blocks. The goal is to manipulate the blocks to achieve some selected goal pattern (ex. block a on top of block b). In order to manipulate the blocks with the arm to achieve the particular stack pattern, planning must be done. If actions are randomly performed, the goal state might never be achieved. Since the domain can be enumerated (the operations, objects and states) and the problem can be broken into smaller problems that will eventually lead to the solution state, it is a prime candidate for use of a planning technique to get the solution.

In a successfully implemented planning system, there are five things the system must be able to do (adapted from [Rich, 1991]):

Choose a rule that best applies to the problems current state.
Apply the rule chosen and update the state of the problem.
Identify the solution when it is found.
Determine when a dead end is reached.
Detect a solution that is close to the goal state and apply special techniques to try and reach the goal state

There are two main approaches to this type of problem solving, weak based and search based. Weak based methods rely on cases or rules to find problem solutions. They are considered weak because these methods can only be applied to certain types of problems Search based methods are those that use heuristics or classification techniques within a hierarchical search space That is, they apply domain knowledge to help find a solution. These methods can be applied to a much wider set of problems. Linear, non-linear, rule based and hierarchical planning are all techniques used when solving planning type problems. Linear and non-linear solutions are weak methods based on rules. Hierarchical planning uses search methods. Other methods include reactive planning [Brooks, 1986; Agre and Chapman 1987; Kaebling, 1987], triangle tables [Fikes *et al.*, 1972; Nilsson, 1980], metaplanning [Stefik, 1981a, 1981b] and Macro-operators [Fikes and Nilsson, 1971].

2.2.2 Linear and Non-linear Planning

Linear planning is the set of planning problems that can be solved in sequential order, one sub-goal at a time. STRIPS [Fikes and Nilsson, 1971] is a classic example of linear planning. Non-linear planning is the set of planning problems that cannot be solved in this fashion. These problems are much more difficult to solve. In non-linear planning problems sub-goals interact such that their solutions must be found in a concurrent fashion. This allows for partial ordering of the sub-goals as the process proceeds as solutions are found. At any one point, there might not be a clear picture as to the construction of the final goal state but as the process goes on, the solution emerges.

NOAH [Sacerdoti, 1975] and NONLIN [Tate, 1977] were two of the first non-linear planning systems implemented [Rich and Knight, 1991]. Later planning systems such as MOLGEN [Stefik, 1981a, 1981b] and TWEAK [Chapman, 1987] expanded the non-linear planning technique by adding constraint posting.

MOLGEN is a system that plans scientific experiments. It is a system that is separated into levels. Each layer controls the next by some degree. This type of layered organization is termed meta-level architecture [Jackson, 1999]. Each level in MOLGEN represents a planning space. The first is the strategy space that reasons about plan steps within the design space. Reasoning is done using both heuristics and least commitment. The next level is the design space. It proposes certain operations and revises the ones that don't satisfy the goal. Once operations are identified, the information is passed to the last level, which is the lab space. In this space, operations are sorted, screened, merged and transformed to produce a refined solution to the given problem.

2.2.3 Rule Based Planning

Rule based planning, like linear and non-linear planning, is a weak method for solving planning type problems. This method uses a set of domain-specific rules to reason about the problem and find a solution. This method is difficult to implement because, as with all planning problems, a closed world must be assumed and it is extremely difficult to represent all domain knowledge in rule form. R1 [McDermott, 1980, 1981, 1982] (commercially known as XCON) is a system that performs planning. This system configures VAX systems. Another well known system that uses rules is MYCIN. MYCIN uses rules within the domain of the treatment of blood infections. While MYCIN performs diagnosis and not planning, it is a good system to evaluate when looking at approaches to using rules to solve problems.

One of the main differences between R1 and MYCIN is that MYCIN is hypothesis driven whereas R1 is data driven. Here, R1 will be discussed since it performs planning which is a main focus of this thesis. There are two kinds of knowledge needed when configuring VAX systems. These are knowledge about the system components and the constraints that must be followed for successful configuration. R1 contains 10,000 rules. A key to R1's success has been the inclusion of domain-specific control knowledge in these rules, that allows the system to reason about and make a decision as to what to do next. R1 uses its domain knowledge of which components need to be included as well as the constraints placed on the configuration. Using the needed components as a goal, it uses constraint and domain-specific control knowledge to select a component and add it to the configuration. During this process, the rules are used to maintain the constraints, and assure correct configuration and inclusion of all components.

2.2.4 Hierarchical Planning

Hierarchical planning techniques include problems where the domain knowledge can be ordered in a hierarchical fashion. This type of operator organization greatly reduces the number of operators to select from. ABSTRIPS [Sacerdoti, 1974] is a system which uses this technique. This solution introduced the idea of abstraction spaces where lower level preconditions are ignored until higher level preconditions can be met. This method allows the elimination of extra work that might be done by a system using a non-linear technique. This is seen because operators will not be selected if they are not producing a path closer to the solution due to the hierarchical nature of the preconditions. In hierarchical planning, operators that are dependent upon each other are ordered so that the most important preconditions must be met first. The operator preconditions each have critical values associated with them. Operators that are dependent upon preconditions that cannot be met are never considered. The operators with constraints with the highest critical values will be encountered first. If these operators preconditions cannot be satisfied there is no need to attempt to satisfy the preconditions associated with the operators below it because they are dependent on the first operators preconditions being met. Later systems will take the ideas behind hierarchical planning and use them in ways to solve more generic problems.

2.2.5 Case-Based Planning

Case-based reasoning is a problem solving technique where previous cases of the problem are available for reference, alteration and application when trying to solve a new case. Cases of problems are stored in a case database and are referenced when a new problem is introduced. There are five processes involved within a case-based system [Allen, 1994]:

Presentation of the problem to the system.

Retrieval of close matching cases from the case database.

Adaptation of the current problem closer to the closest matching cases to create a solution to the problem.

Validation of the solution by the user or environment.

Update of the database to include the newly generated solution.

These processes are used to generate solutions to problems within the domain of the case-based system. The system is given a problem to solve. The database is then queried and, using heuristics to identify similar cases in the database, returns the cases that are similar to the current problem. These cases are then used to generate a new solution that is somewhere between the similar cases and the new case. The generated solution is then validated by the user or the environment. Validation involves input from the user or the environment signifying that the solution satisfies the goals. If the solution is found to be applicable through the validation process, the solution is added to the database of available solutions so that it can be used later to solve a different problem.

SMART [Acorn and Walden, 1992] is a system used by Compaq for customer support. It is an integrated call-tracking system that also handles problem resolution of diagnostic problems. The system uses case-based retrieval of hundreds of cases. Most commercial case-based retrieval systems have focused on customer support and avoids the adaptation step by simply returning the closest case available as a solution [Allen, 1994].

Another case based reasoning system in a similar domain to Meal Planner is CHEF [Hammond, 1986]. This system creates recipes in the Szechwan cooking domain. The system input is a list of goals that the dish must satisfy such as taste, texture, etc. The output is a recipe that will satisfy those goals. This system works by retrieving a recipe in the database of previously created recipes that satisfies some of the goals of the user. It then modifies that recipe, keeping components that satisfy the goals and replacing components that will not satisfy the goals. Modification of the recipe can sometimes cause problems. If factors, such as cooking time and preparation, are not considered, a potential solution to the desired goal might be destroyed. Processes are necessary to identify such problems and suggest fixes so that the modifications are not counterproductive. Once a recipe has been accepted, it is added to the database of recipes to be available as a possible semi-solution to future recipes to be generated. A failed recipe is also retained with a list of the repair strategies for the given goal. This information is used for future recipes in order to detect problems prior to recipe failure.

Case-based techniques are important because many problems can benefit from previous problem solutions similar to the current problem. The problems with case-based problem solving are that adaption is difficult to implement and does not always produce a desirable result. As with planning, search can become intractable for large databases so matching the needs to the solutions must be efficiently executed. User interaction is also important since there is no automated way to validate the resulting solutions.

2.3 Generic Tasks

In the late 1970's implementation of MDX [Chandrasekaran, 1983a], a medical diagnostic system, introduced the idea of problem solving as a classificatory problem. This research eventually led to the theory of Generic Tasks [Chandrasekaran, 1983b, 1986]. The Generic Task approach, unlike the other techniques discussed, provides a means for creating wide ranging solutions to a variety of problem types. As introduced earlier, there were six Generic Tasks identified as elements for implementation of a knowledge based system: Hierarchical Classification, Hypothesis Matching, Knowledge-Directed Information Passing, Object Synthesis by Plan Selection and Refinement, State Abstraction, and Abductive Assembly [Chandrasekaran, 1983b, 1986].

Tools have been created to aid in building knowledge based systems using these tasks [Josephson and Josephson, 1994]. CSRL [Bylander and Mittal, 1986] was created to apply Hierarchical Classification. HYPER [Johnson, 1986] was developed for the task of hypothesis matching. IDABLE [Johnson, 1988] is implemented to apply knowledge-directed data retrieval system, DSPL [Brown and Chandrasekaran, 1984; Herman *et al.*, 1986] implements plan selection and refinement, and PEIRCE for Abductive Hypothesis Assembly [Punch, 1986]. An algorithm based on the Generic Tasks was developed for solving routine decision making problems in 1997 [Fox, 1997, 1999b, 2000b] and used to implement 2 systems, Shopper and Routine Scheduler[Fox, 1999a].

Shopper is a consumer decision making system that decides what groceries to buy at the store based on base nutritional requirements and food preferences and the user's economic situation. The meals and foods are arranged using hierarchical classification. The system is given a list of needs in terms of the number of meals. With this input, Shopper generates the meals that the consumer might desire. Interaction with the user helps the system gain more knowledge about the plausibility of potential meals. Needs are then filled starting with the highest rated meals. Food items are then generated and selected based on the consumers needs taking into consideration economic, preference, and nutritional constraints.

Routine Scheduler is a scheduling system that schedules classes and instructors to teach those classes for a small Computer Science department. This system also takes in as input the classes that need to be taught, the available instructors, and the preferences of those teachers to teaching the classes. This system uses the Routine Decision Making algorithm to create the schedule of classes and instructors considering all constraints including personal preferences of the instructors.

2.4 Conclusion

Nutritional meal planning combines many of the techniques just discussed. Hierarchical classification is used to order the domain knowledge in a logical fashion. Non-linear planning is seen when multiple pathways are found to be applicable to the current sub-goal. When this happened, all applicable pathways are explored as possible solutions to the problem. The ideas behind using previous solutions to a problem as seen in case-based planning are used. Previous meal plan solutions are available to better tune the system to construct more appealing meal plans. The algorithm used to find and construct a meal plan is based on Generic Tasks. These tasks are used to reduce the implementation complexity as well as the performance complexity of solving the search based problem of meal planning.

CHAPTER III

NUTRITIONAL MEAL PLANNING

3.1 Routine Decision Making Algorithm Introduction

Routine decision making is a sub-category of decision making where decisions are made on a domain of knowledge that is well known and knowledge obtained from previous solutions within that domain are available to assist in creating new solutions. There are many problems that can be considered routine. Planning daily activities, selecting groceries, selecting clothes to wear, and planning what to eat for the day are examples of routine decision making. These problems can also be considered planning problems since the decisions that are being made are steps applied toward a goal. Routine decision making is an interesting problem that has been studied for many years by computer scientists in the field of artificial intelligence.

Prior research [Fox, 1997] has developed a domain-independent algorithm based on the Generic Tasks described in chapter 1. The algorithm utilizes three of the Generic Tasks identified within the Generic Task paradigm: Hierarchical Classification, Routine Recognition and Abductive Assembly. This algorithm uses variations of these tasks to perform: Plan-Step Generation, Plan-Step Assessment, and Plan-Step Assembly. Figure 3 shows a graphical representation of the three tasks. Plan steps are the choices or actions available to create a solution. They are arranged hierarchically from general to more specific elements or actions. The routine decision making algorithm first generates potentially useful plan-steps that are as specific as possible (Plan-Step Generation). Recognition agents use Routine Recognition to determine how effective each plan step is (Plan-Step Assessment). The plan-step assembler determines the effectiveness of a particular plan-step and selects the combination that best meets the needs of the user (Plan-Step Assembly). Constraints on the selection of choices are applied during plan-step assembly. Constraints are categorized based on strictness. For example some constraints are rigid constraints that cannot be broken, while others are mild constraints that, while not completely desirable, do not rule out options until better options are found. The assembler rates a plan step higher if the plan step is more specific and or it meets multiple needs of the agent. Plan steps are discarded if they violate rigid constraints and their utility is lowered if they violate mild constraints.

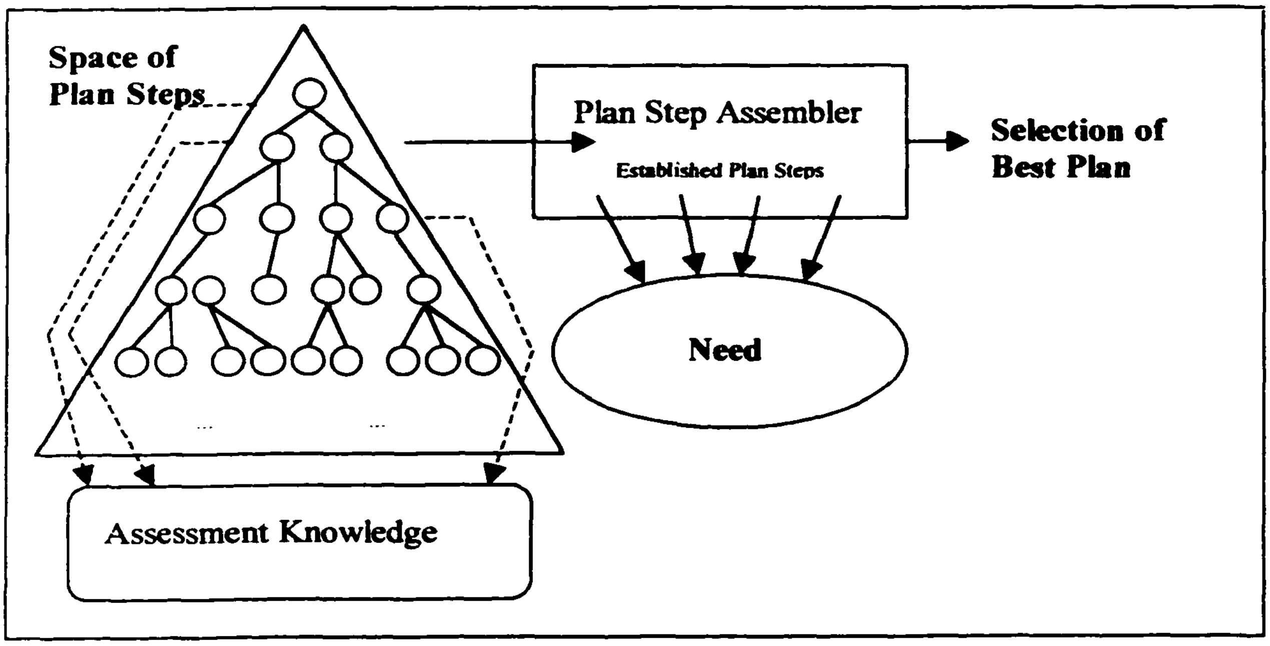

Figure 3 Plan-step Generation, Assessment and Assembly

3.2 Nutritional Meal Planning as a Problem

Nutritional meal planning is a routine decision making problem. It involves both planning and decision making processes. Recall that in routine decision making, the situation is one where the problem has been solved many times before; and the previous solutions are available to apply to a new problem of the same type. Routine decision making is shown in Figure 4.

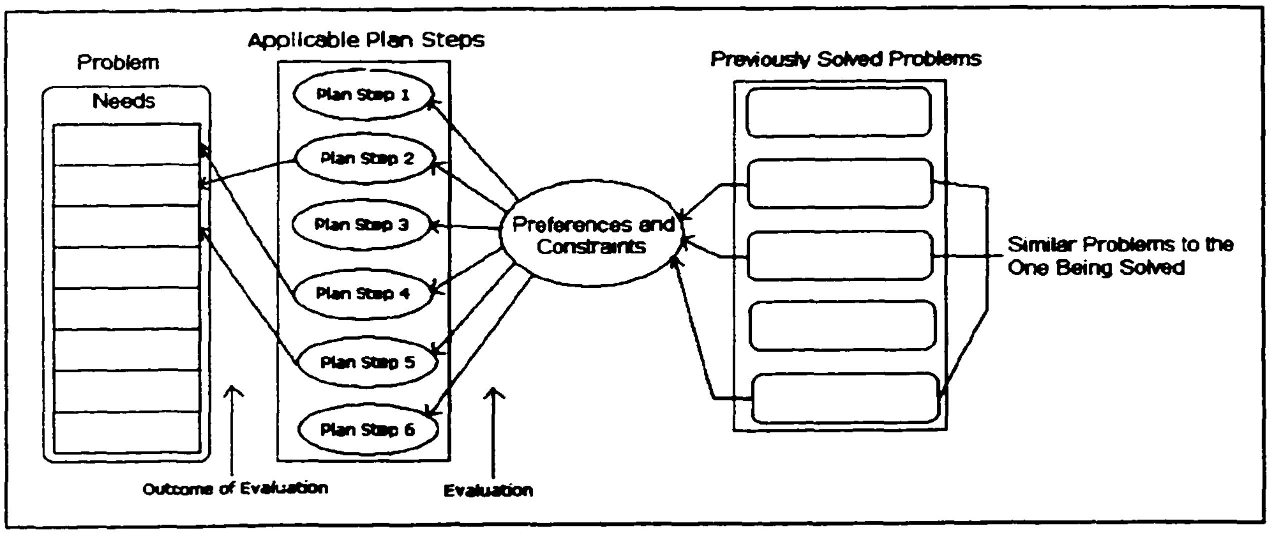

Figure 4 Routine Decision Making

This figure shows that preferences and constraints are used, along with the knowledge of previous solutions that are similar to the one being solved to select from the generated applicable choices and fulfill the users needs.

Nutritional meal planning is part of everyday life; therefore many previous solutions are available to solve the nutritional meal planning problem. While solutions to meal planning are available, an automation of the meal planning process that considers a persons nutritional needs and personal preferences is not available. These solutions can be used as guidelines to help in the planning and decision making process to achieve desirable solutions to new meal planning problems. In order to successfully solve the meal planning problem, recipes must be generated that will potentially fulfill the user's needs. Once the recipes are generated, they must be evaluated as to how well they fit into the desired goal state, which in this case is the meal plan fulfilling both the users nutritional and personal preferences without violation of user constraints. Once evaluated, the meal plan is assembled from the generated recipes. These steps can be assisted by knowledge of previous meal plan solutions and techniques for making choices determined by past meal plan generation.

3.3 Why Nutritional Meal Planning

Nutritional meal planning is the selection of meal components (recipes) to create a particular meal or day's worth of meals, taking into consideration nutritional requirements and constraints. Successful automated nutritional meal planning must not only consider nutritional requirements and constraints but also the food preferences and tastes of the user as well as provide variety. Nutritional meal planning is a time consuming routine decision making task that, to some extent, is done by at least one person in any household. As nutritional and preferential considerations are considered, this task takes more time and becomes considerably more difficult. This makes the meal planning problem an ideal candidate for implementation using the Generic Task routine decision making algorithm (described in section 3.1). Implementing this problem as a rule based system, as MYCIN and R1 were implemented, would be time consuming and complicated considering the many nutritional constraints, rules, preferences and foods that need to be considered. Using the Generic Task routine decision making algorithm makes the organization and implementation of this problem much easier.

There is also the practical side to this problem. Every year many people begin to follow altered eating habits, healthy or not, in an attempt to lose weight or become healthier. Many people are placed on restricted plans for health reasons such as diabetes or heart problems. Most of them do not stick to their new eating plan because the plan is too limited, it is not a healthy plan, or it is just too time consuming and difficult to follow. The application of the routine decision making algorithm to recipe selection in nutritional meal planning will demonstrate the effectiveness of this algorithm to routine decision making and make meal planing easier, even when following nutritional guidelines.

3.4 Issues Involved in Nutritional Meal Planning

Meal planning seems, on the surface, to be a fairly straightforward problem; however this is deceiving. Meal planning becomes an extremely complicated problem when one begins to consider nutritional preferences and constraints, as well as the likes and dislikes of the person that will be following the meal plan. The problem becomes even more complicated when a family meal planning is considered because each family member has different nutritional constraints and nutritional and food preferences.

There are many things that need to be considered when creating meal plans. Dietary requirements such as calorie, fat, vitamin, mineral and fiber intake are important. If a person has health problems such as diabetes or heart disease, is health conscious, or is trying to lose or gain weight, special restrictions might need to be considered and monitored. These restrictions might include the number of calories to be consumed, the percentage of fat intake or the amount of sodium intake. Allergies or intolerance to specific foods must also be considered. These considerations themselves make meal planning complicated, but they are not the only considerations that need to be made.

Once nutritional restrictions are considered, individual preferences such as likes and dislikes of certain foods must be factored. A meal plan that satisfies the dietary requirements and restrictions of a person but does not satisfy personal taste is not useful. The combination of nutritional and personal restrictions, when applied to meal planning, creates a large and difficult planning problem due to the complexity of this combination. When these restrictions are then added to the intractable search through all possible recipes to match the desired meal components (ex. entrée, side, drink, etc.) for the specified meals (ex. breakfast, lunch, dinner, etc.), along with the necessary component of variety, the problem becomes yet more complex. Meal Planner solves the complex nature of this problem by applying an algorithm to this problem that both reduces its complexity by making the recipe search tractable and allows preferences and constraints to be included and used in an efficient way.

CHAPTER IV

MEAL PLANNER

4.1 System Introduction

Meal Planner is a hybrid knowledge based and expert system that creates meal plans for single users based on their personal and nutritional preferences. Currently, the system is composed of 110 recipes (including their nutritional information) as part of its knowledge base. Other knowledge includes personal user information, user constraints and user preferences as well as nutritional constraints, nutritional preferences and nutritional knowledge (see Figure 5).

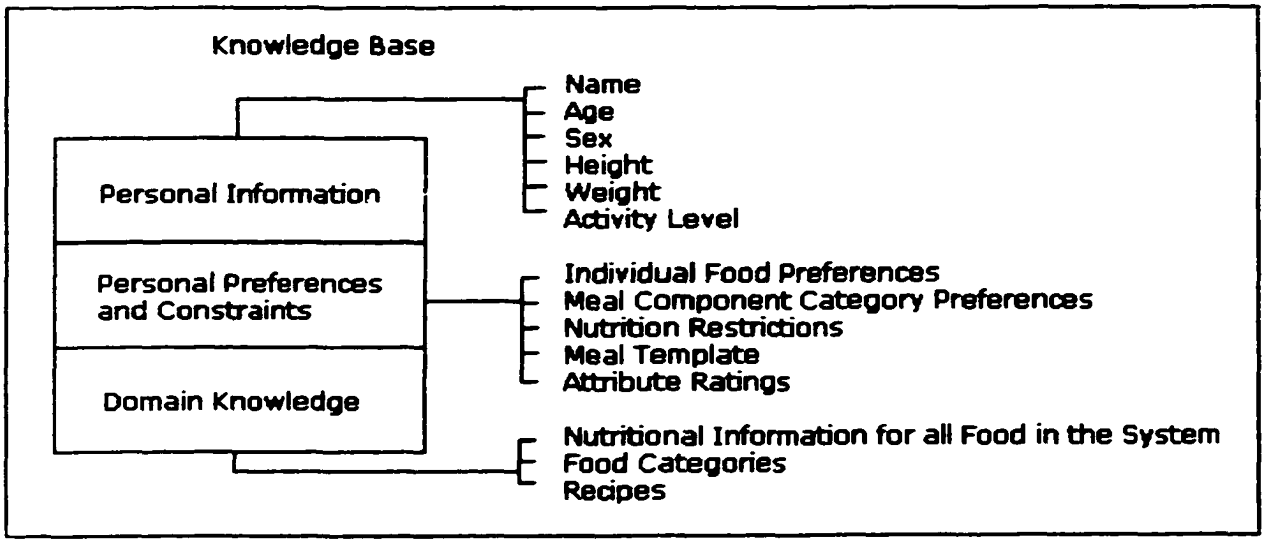

Figure 5 Meal Planner's Knowledge Base

Figure 6 shows the architecture of Meal Planner. The knowledge available to the system is shown in the first two boxes to the left. A hierarchy is used to organize the food categories and recipes. Hierarchical Classification is used to search this hierarchy for potentially useful meal components. Recognition agents, one per food item in the hierarchy, perform assessment. The Assembler performs Plan-step assembly. These system parts will be explained in more detail in later sections.

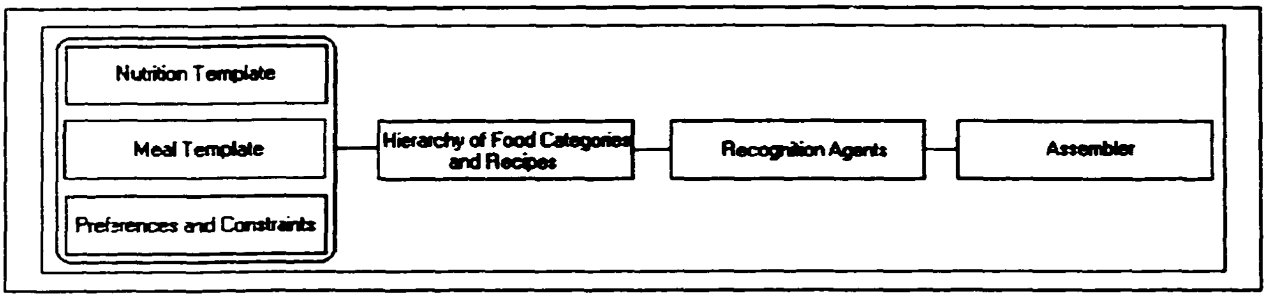

Figure 6 Components of Meal Planner

The user inputs individual preferences and constraints, which are different for every user. This is done with the creation of a profile. This profile obtains user preferences and constraints to be applied by the system when it is creating meal plans. In the profile, the user prescribes the meals she would like to include in her daily meal plan by selecting from breakfast, lunch, dinner, and up to three snacks. The types of meal components that should be included in each meal are also specified, such as entrée, side, or drink. The user decides how detailed the descriptions of the meals will be. For example, meal components can be general categories like entrée, or more specific ones can be defined such as meat based entrée. The user profile is created through a series of questions that the user answers when she first uses the program. This profile is saved and used each time a meal plan is created.

The profile includes personal information about the user such as sex, age, height and weight. This information can be used to determine suggested caloric intake or weight. Suggested caloric intake is calculated using Harris-Benedict equation to calculate the users resting energy expenditure (REE) then adjusting the calories to the user's activity level. Height and weight charts (see Appendix A) are used to determine the users suggested weight. This information can be used to assist a user who would like to use the system to lose weight or eat healthier. The user also specifies any dietary restrictions that she would like to follow. The dietary choices include following a low fat and low cholesterol diet, a limited caloric intake, or the American Dietetic Association Exchange recommendations (see Appendix A). If the user is familiar with the restrictions she would like to follow, such as a restricted caloric intake, and knows the values of the desired restrictions (ex. knows she wants to consume 1800 calories/day), she can directly input the values of the restrictions. Otherwise, calculations are made to determine the best restrictions for the user based on the given personal information.

In addition to nutritional restrictions and personal information, the profile also contains preferences about meals and meal components (described in section 4.2), as well as preferences toward particular food categories. For example, if the user were a vegetarian, she would want to exclude any recipes containing meat. In order to specify preferences, food categories are first given to the user and the user specifies her preference for that food category. The user can also specify particular foods that are disliked or foods that she is allergic to. A food category that is not preferred at all is excluded when meal plans are created. Since a category is completely excluded if it is not preferred, this type of exclusion should only be used in extreme situations where *all* foods and recipes that fall into the category should be excluded. This might be the situation if someone is allergic to a specific type of food or is a vegetarian. If these specified foods are included as an ingredient in a recipe, the recipe is excluded from the recipe selection process. These exclusions are separated from the profile itself since, as the system is implemented now, there is not an easy way to update the profile without completely recreating it. Foods can be added, when desired, to the list of undesirable foods at any time. These foods are used to compare to the ingredient list of each recipe to identify if that food is included in the recipe. If the food is included in the ingredients of a recipe, then the recipe is rated lower than if the undesired food is not in the list.

4.2 Nutritional Meal Planning Domain and Knowledge Representation

The nutritional meal planning domain includes nutritional and personal information given by the user. This domain is composed of nutritional constraints that the user would like to follow (such as limited fat or low sodium intake), meal template information (such as meals the user would like to eat like breakfast, lunch, dinner, and a snack), the food categories that each meal should consist of (such as dinner entrée, vegetable side order, drink, etc.), and personal likes and dislikes of foods (such as the user likes strawberries but hates mushrooms). The plan steps are arranged as a hierarchy of food categories, food types and specific recipes. When Meal Planner is started, the hierarchy of plan-steps is created from a database on disk. This hierarchy consists of recipes and foods categorized from general categories like breakfast, lunch and dinner to individual foods and recipes that will eventually be selected to create the meal plan (Figure 7).

Each level of the hierarchy represents a different level of food classification. Food classification and categories have been chosen that would allow for flexibility and versatility for creating meal plans. There are seven levels in the hierarchy not including the recipe at the lowest level of the hierarchy.

Food-	The starting point and most general classification
Target Meal Types-	Divides food into meal categories such as breakfast, lunch or dinner food.
Portability-	Divides food into whether the food is an Eat-in or Take-out food. This level can be used when meal plans will be created to include lunch eaten at work for example.
General Component-	The first of the actual meal component levels. It identifies general meal component classifications such as dinner entrée and lunch side order.
Preparation Time-	Divides recipe's into different preparation times, less than ½ hour, ½ to 1 hour, or more than 1 hour to prepare. This will be used when the user identifies they need meal plans that can be prepared in an approximate length of time.
Specific Component-	Food components are classified more specifically. For example, Dinner Entrée can be classified as Pasta Entrée, Meat Entrée, Vegetable Entrée, etc.

Advanced Component- This is the final classification level before individual recipes are found. This level expands the Specific Component classifications. For example the Meat Entrée category is expanded into the specific meat types such as Beef, Pork, Poultry, Pasta, red-sauce based, white-sauce based, etc.

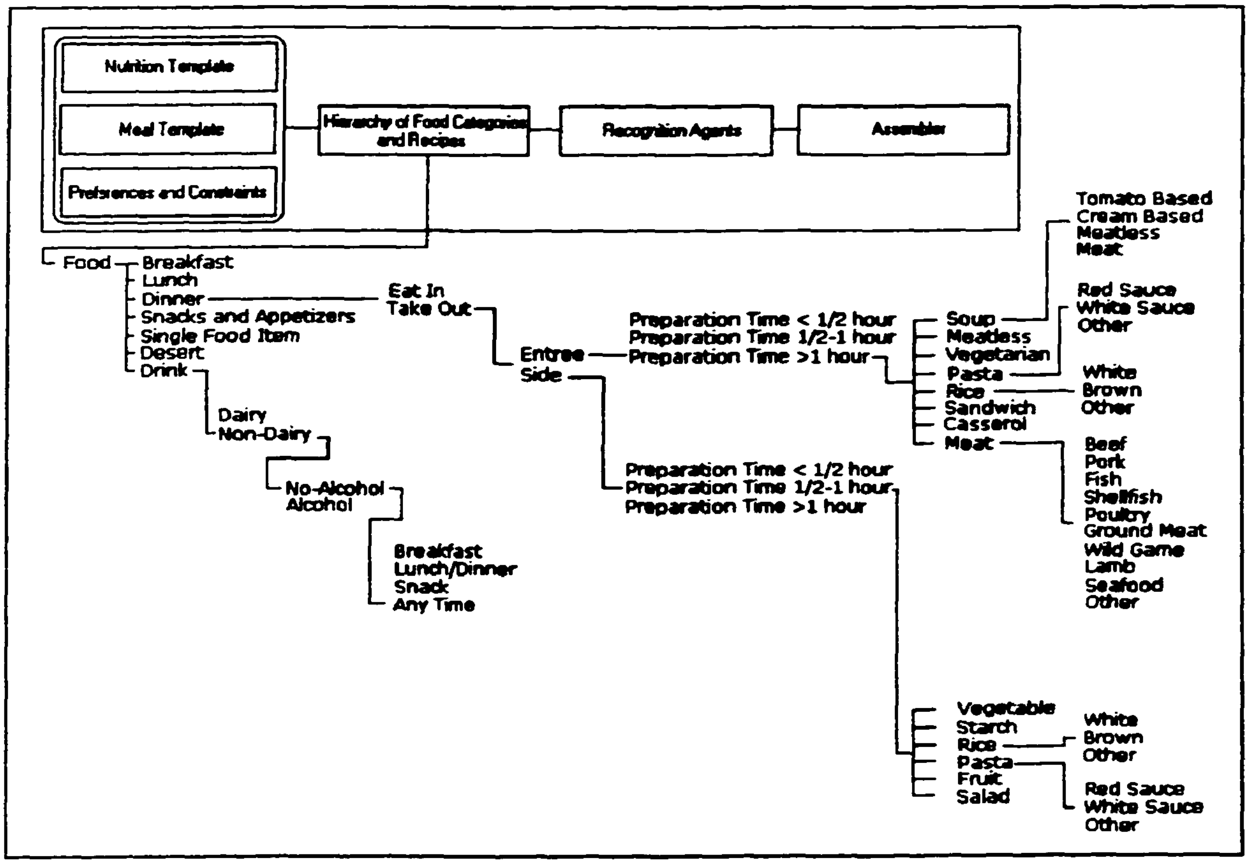

Figure 7 Partial Meal Planner Hierarchy

Each node in the hierarchy has a specially defined recognition agent, used when examining a given meal category to determine whether a particular food category should be established as a possible choice for the current case. All food categories are considered but only those that are found to be applicable are refined. Refinement involves moving from the established category to the category's children, attempting to establish any or all of them. Once recipes have been identified as established or discarded, the assembler then takes the nutritional and personal constraints of the user and discards plan steps that violate those constraints. It then rates the remaining recipes and selects the best choices of plan-steps to meet the user's needs and preferences. This process is elaborated on in sections 4.4 and 4.5.

4.3 Determination of Needs and Preferences

In order to most effectively accomplish the goal of generating a day's worth of meals that meet the user's specifications, the system first requires some information about the user in the form of a personal profile. This profile is saved and used for meal plan creation. Multiple profiles can be created if variability in the profile is desired. If a second profile is created, future meal plans can be created based on the new profile or the old one. The profile is composed of several elements: personal information (name, age, sex, weight etc.), nutritional constraints (special diets, low sodium, low fat, restricted calories etc.), a meal template (which meals to have in a day), meal components for each meal selected ordered by importance (entrée, side order, drink etc.), and user rankings of decision criteria (to be described later). These elements are shown in Figure 8.

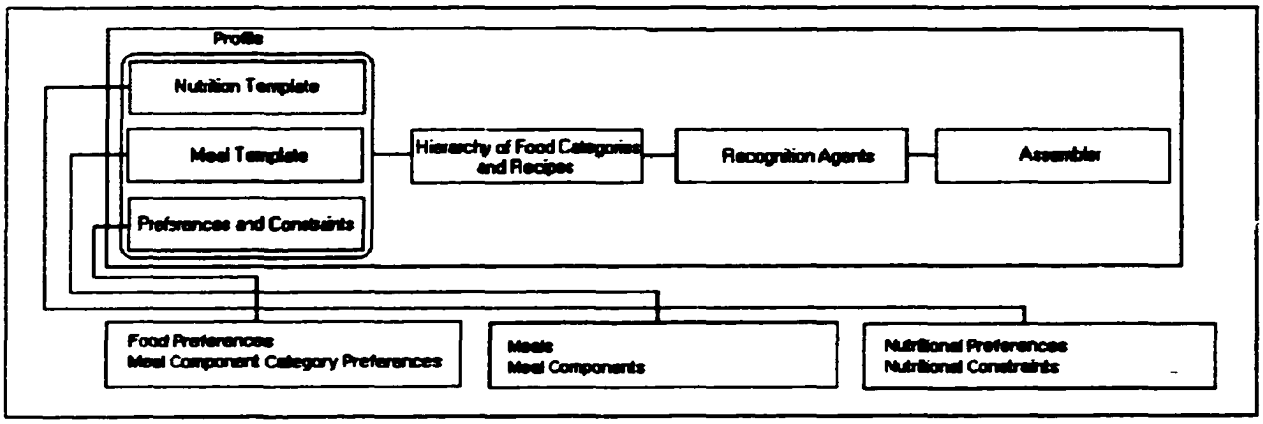

Figure 8 Profile Description

Personal information is asked of the user in order to monitor nutrition information. A meal template is created so that the user can define her/his eating habits. Meal components are ordered so meals can be personalized to the way the user is used to eating.

The user answers a set of questions about their height, weight, activity level etc. These values are used in calculations to insure that the meal plans for the user will meet recommended daily allowances as defined by the Food and Drug Administration[1] for the user based on their profile. If special dietary restrictions (such as restricted caloric intake) are requested by the user, the responses to these questions are used to calculate and compare requested restrictions to the calculated minimum boundary recommended for each restriction being requested based on the users' profile to make sure that healthy meal plans are created. Other personal information includes specific food preferences and dislikes. Any recipe consisting of preferred foods will be rated higher and any consisting of disliked foods will be rated lower. Recipes can also be selected as favorites which positively affect their ratings when being evaluated. Preferences for food can be established in two ways. When answering the personal information the user has the

[1] Recommendations based on the Food and Drug Administration's Daily Reference Values (DRVs) and Reference Daily Intakes (RDIs)

option to work through a list of meal component categorizations such as Meat Entree or Sandwiches. The user considers each item and rates them based on her preference for each meal component categorization. Another option is to rate specific ingredients as desired.

Meal expectations and nutritional requirements that the system will try to follow are also input. The user indicates which meals will be taken each day. These consist of any combination of breakfast, lunch, dinner, and up to three snacks. These choices allow for flexibility in personal preferences in eating habits. The user next indicates meal components (such as dinner entrée, side, dessert, etc.) that each meal should consist of along with each component's importance (see figure 9). Each main meal (breakfast, lunch and dinner) can consist of up to 10 meal components whereas snacks are limited to five meal components. This allows for additional variability in eating habits. A person that eats six small meals instead of three large ones has enough flexibility in the number of meal components within a "snack" to define it as a small meal if desired. When the meal templates are created, a rating is assigned to each of the meal components as to its importance of being included in the day's meals. This is done so that, if nutritional constraints are expended before the entire meal template is filled, the most important meal components are included and less important elements are omitted from the day's meal plan.

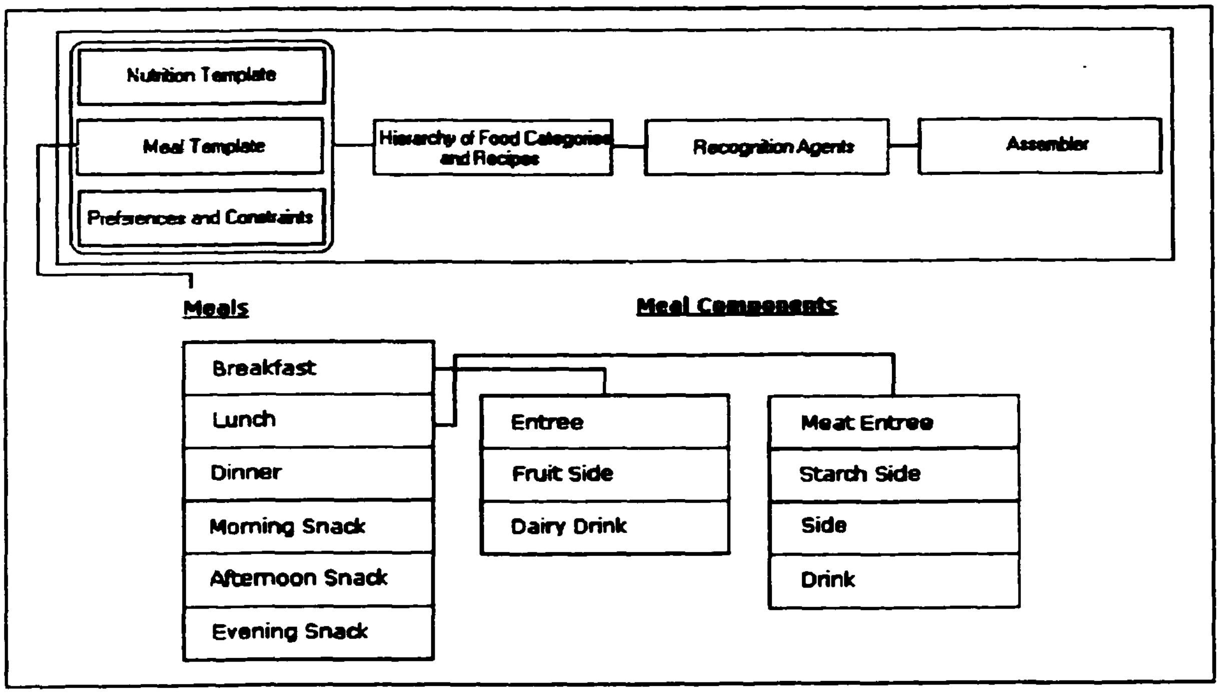

Figure 9 The Meal Template

Consider, for example, a user who has indicated that she would like to eat three meals and three snacks in a day but wants to restrict her caloric intake to 1800 calories. The 1800 calorie restriction might be met before all the meal components for all meals and snacks are filled. The most important meal components, such as dinner entrée, lunch entrée, and breakfast entrée, are filled first leaving less significant components to be dropped from the days meals and snacks if necessary. The nutritional constraint of 1800 calories is a more rigid constraint than filling all meal components.

Additional questions are asked about nutritional constraints that should be followed such as low sodium or fat intake, follow a special diet, etc (see Figure 10). There are several choices. The amounts of fat and cholesterol, sodium or both can be restricted. The American Dietetics Association exchange guidelines can be followed (either using carbohydrate counting or exchanges/calorie level). If the exchange plan is selected, the user must set up the maximum number of exchanges she would like to consume. If the user is unfamiliar with these guidelines, the recommended calorie consumption is computed based on the user's height, weight and activity level. The user can select from sets of exchanges for different calorie levels.

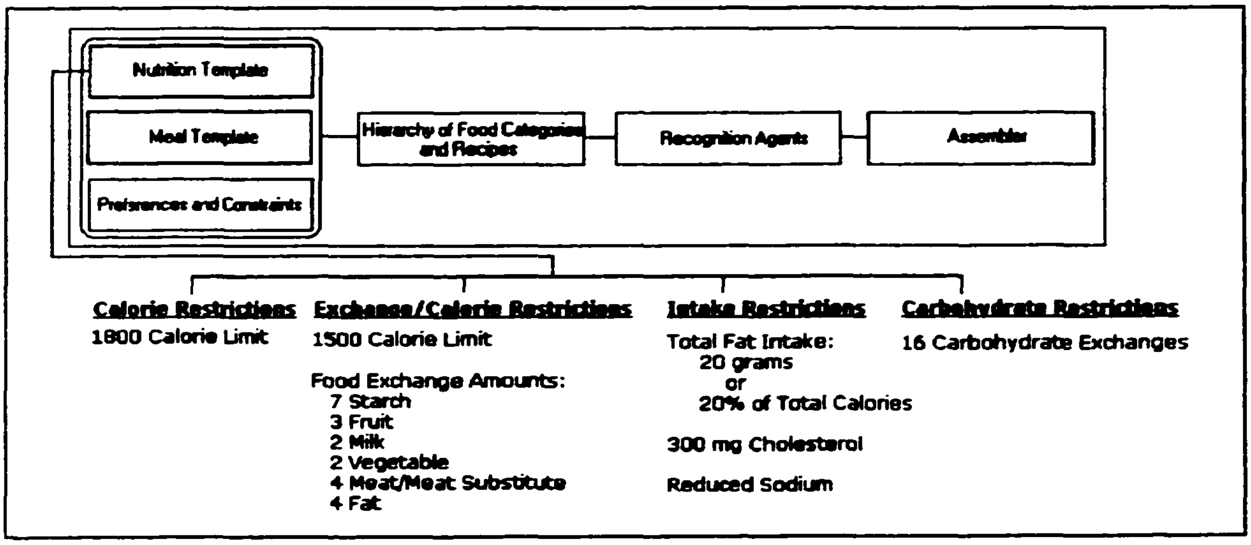

Figure 10 The Nutrition Template

Each user has her own unique nutritional goals and food preferences. A balance of nutrition and personal preferences needs to be maintained for successful meal planning. For any one person, this balance might be shifted one way or the other. One person might be extremely health conscious while someone else might care more about eating foods that she likes and less about eating healthy. Six attributes that need to be considered in automated meal planning have been identified. These attributes denote the considerations that are made in meal planning when balancing nutrition and personal preferences.

The user rates each of these six attributes on a scale of 1 to 5 based on its importance. These attributes are: the match of the meal item to the meal component being filled, the match of the meal item to the nutritional exchange template, history as to how long it has been since the item/recipe has been selected, how strongly preferences for the ingredients the recipe/meal component consists of should be weighed, how strongly selection of a "favorite" recipe/meal component should be factored, and randomness. The match of the meal plan to the meal component determines how important it is that all the meal components within each meal are filled. Someone less concerned about nutrition and more about eating a specific way would rate this highly. Matching the nutritional exchange template determines how important it is to stay within nutritional exchange restrictions. Someone on this specific eating plan would rate this highly. The history rating determines how important it is that a recipe is not repeated frequently. This rating can provide for greater or lesser variability. The rating for preferences for foods positively influence any foods that the user has defined as being liked. Selection of "favorite" recipes will occur more often if its corresponding rating is high. Randomness is the last rating and it allows for variation in the meal plan even though some nutritional constraint may be violated.

These attributes and their ratings work together to provide a balance between personal preference, nutrition, variability and randomness. An equation is used that contains each of these attribute ratings. The algorithm used is as follows (U signifies user rating, R signifies the recipe's match rating to the given category):

(U History * R History) + (U Meal Template * R Meal Template) +
(U Nutrition Template * U Nutrition Template) +
(U Randomness * R Randomness) + (U Favorite * R Favorite) +
(U Ingredients * R Ingredients) = Final Recipe Rating

This equation is applied when decisions are made about which recipes/foods to select to fill meal component requirements. Using this equation allows for variability in the meals, as well as selection of favorite foods while maintaining nutritional goals.

4.4 Plan-step Generation and Assessment

The generation of a meal plan begins with a hierarchical search of the possible meal components to find recipes that will fill the requirements of the user's meals while maintaining nutritional constraints. The user has previously rated each meal component within the meal template, and that rating is used to determine the order that the meal components should be filled. The meal templates with their associated meal components and nutritional exchange templates are used by the recognition agent to identify potentially useful plan steps (food categories) for the creation of a meal plan. The highest rated meal component that has not already been filled is always selected. The recognition agent applies the six criteria as established by the user to evaluate each meal component to recognize whether the node is applicable to the current meal component. If a node's score exceeds a predefined threshold for applicability, the node is established. Food categories that do not establish are discarded. Refinement is attempted for any established nodes by attempting to establish the nodes in the next classification level. Each recognition agent at the new classification level establishes or rejects the node it is associated with.

Figure 11 demonstrates the action of the recognition agents. Two pathways that were established during the indicated searches are shown. Each node has its own recognition agent. The recognition agent establishes the node and then it is refined at which time an attempt is made to establish the children of the established node. This process produced the results shown in Figure 11. This process of establish and refine is repeated until all possible recipes that fit the current meal component have been identified. These recipes are then returned to bc used in the next step of the process, Plan-step Assembly which will be discussed in the next section.

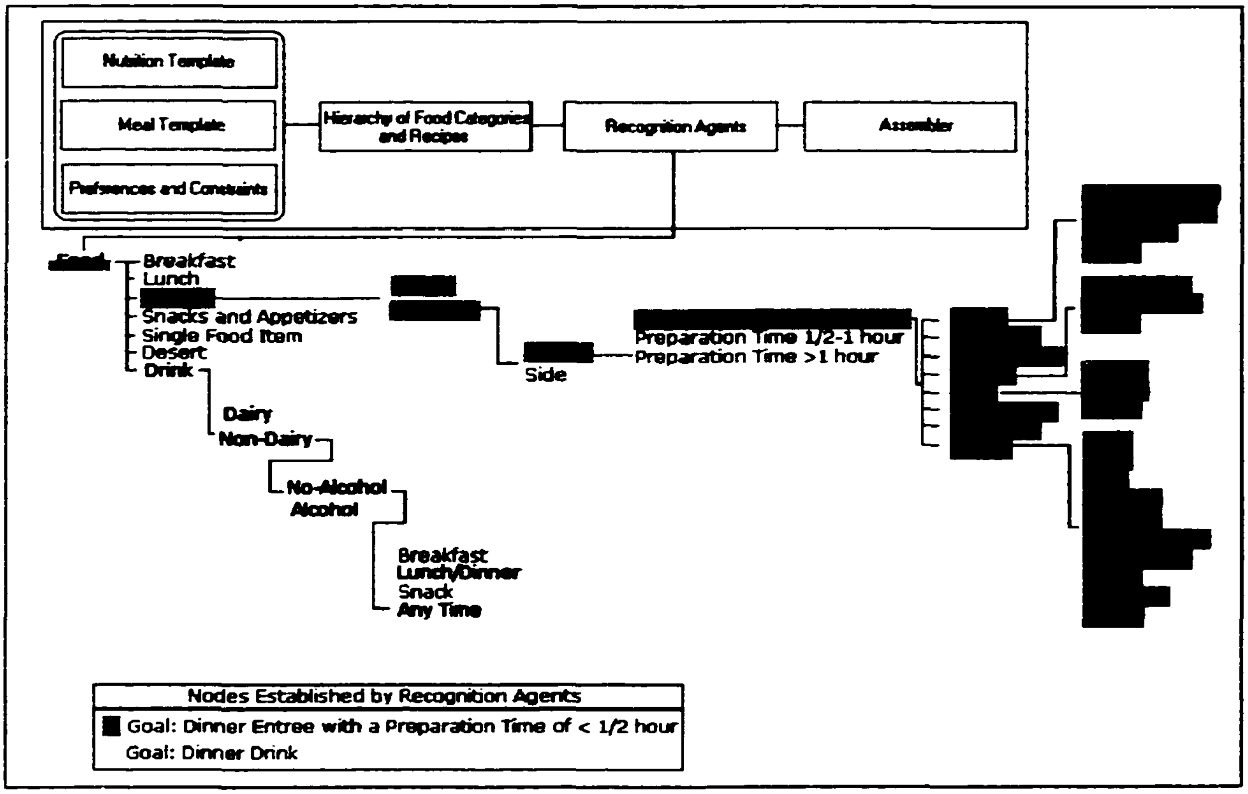

Figure 11 Plan-step Generation Using Establish and Refine Methods

An example of Plan-Step Generation is as follows. The highest rated meal component such as Dinner Entrée is selected (see Figure 11). The food recognition agent is invoked and establishes the node. The next category level contains target meal types (breakfast, lunch, dinner etc.). The recognition agents within the next classification level reachable by the established node at the first level evaluate their nodes. Dinner is the only food category to exceed the applicability threshold at this classification level so it is established and all others are rejected. In refining, the next level is examined. This level contains categories of whether or not the recipe is an Eat-in or Take-out food. The recognition agents evaluate the nodes based on the available information. The user has not specified preference for a take-out meal, so both recognition agents' evaluations meet the threshold and these nodes are established. Preparation time for the recipe is considered next. Again the user has specified no preference so all nodes exceed the threshold and are established. The next classification level is the first of the meal component classification levels that can be specified by the user when creating a meal template. Dinner entrée is found at this classification level so it is established and the rest of the classifications are discarded. Since more specific meal component information wasn't specified, assessment of all remaining food categories at all remaining classification levels is heavily based on the history of what the user has eaten recently and the users preferences, as well as the other four attributes. At this point refinement of this level produces specific recipes have been identified as potential solutions for the selection of the food component of Dinner Entrée. Another example is shown in Figure 12 where a breakfast entrée is being generated. Two recipes found are Pancakes and Fat Free Yogurt.

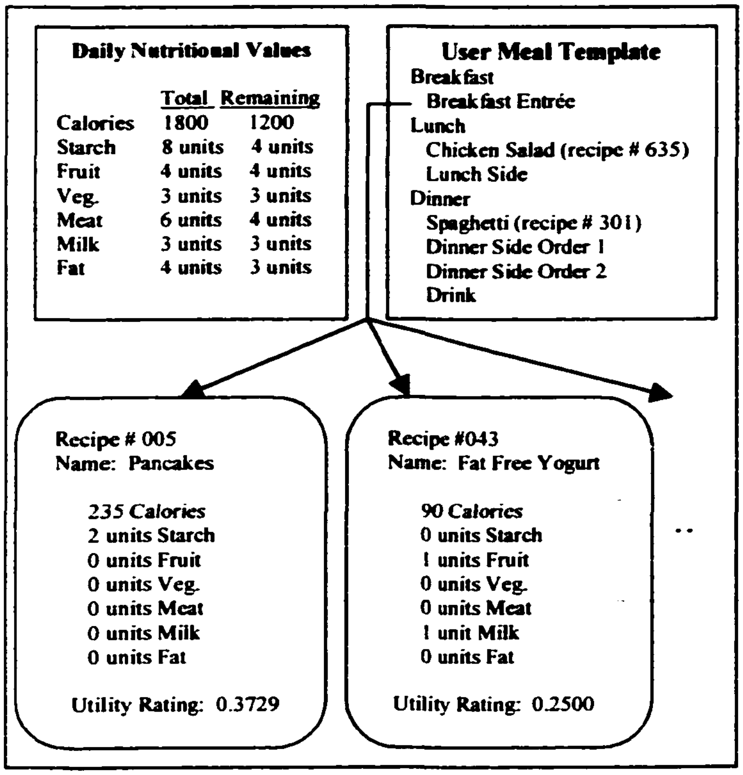

Figure 12 Plan-step Generation

During the establish/refine process selection of potential recipes is made based on the current meal component. Once all applicable recipes are established, the highest rated plan-step (recipe or food) is selected for addition to the meal plan as long as none of the nutritional or personal constraints are violated. When a recipe is found, final recipe ratings are determined in a two-part process. The recipe is first compared to each of the six attributes mentioned earlier and given a rating based on how closely the recipe fits each of those desired attributes. These ratings are then combined with the user's ratings for each of the six attributes to produce a final recipe rate.

When determining the recipe's fit to the six attributes, the user compares the recipe to the meal plan and nutritional template to see how well it fits, taking into consideration any constraints specified. The ingredients are then reviewed to see if the user has identified them either positively or negatively. If the recipe is a favorite, the value for the recipe being a favorite is stored. The recipe is then searched in the history list to see if it is present. A recipe can be found in the history list for 2 weeks once it has been included in a meal plan. If it is found, the rating for history list is lowered by some amount depending on how long it has been since the recipe was used. Lastly, a random value is generated that may either negatively or positively effect that specific recipes rating.

4.5 Plan-step Assembly

Figure 13 shows the process of plan-step assembly. Applicable recipes are passed to the assembler by the recognition agents. The assembler selects the top rated recipe available for the given meal component. The nutritional information for that recipe is considered and compared to the users preferences and constraints. Once the selection of a recipe is finalized, the nutritional information for that day is updated. Once a recipe has been inserted into the meal plan, the next most important meal component is selected and the process of plan step generation, assessment and assembly is repeated. This continues until the meal template is filled or the desired nutritional needs have been met, whichever comes first.

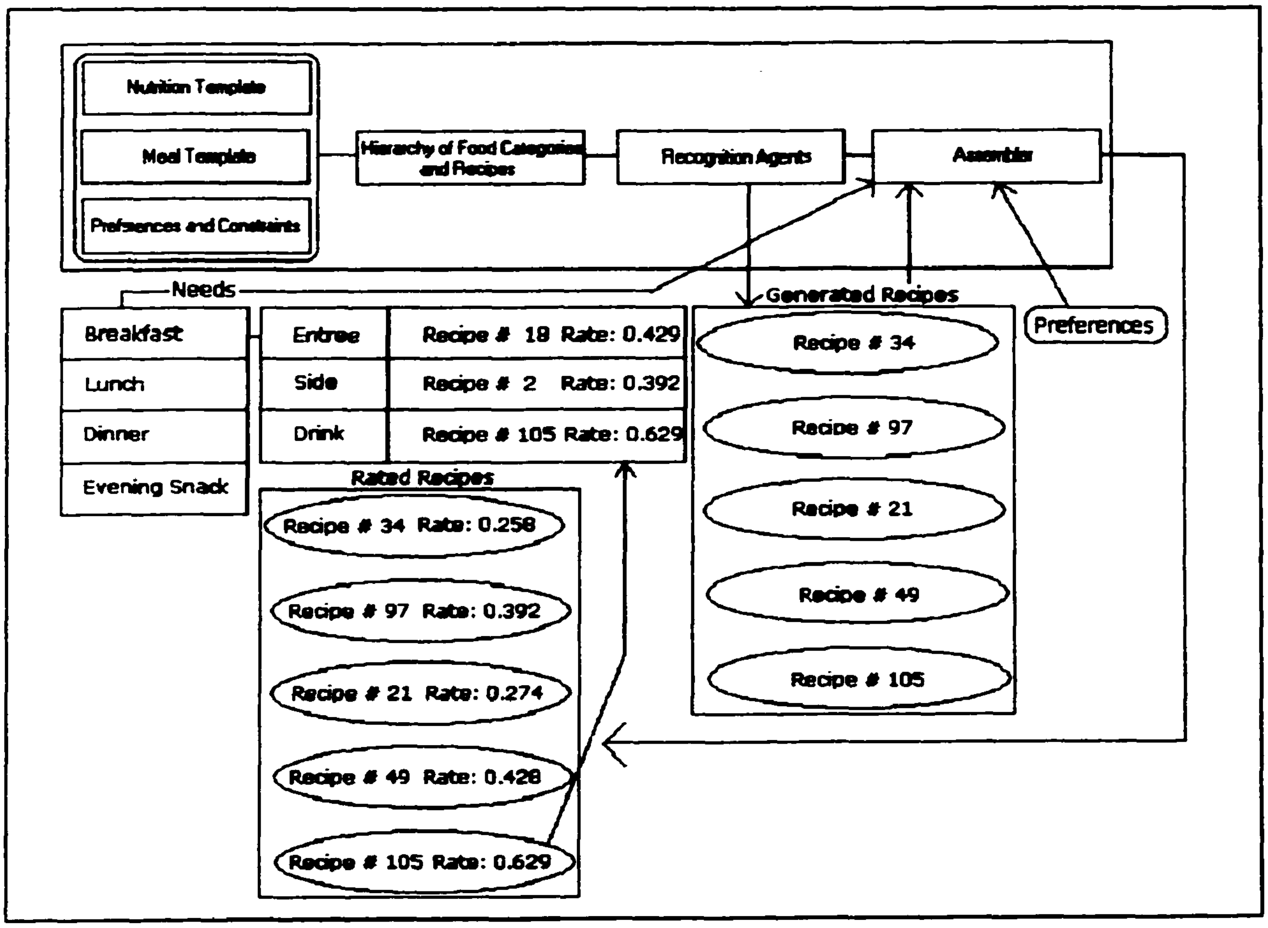

Figure 13 Plan-step Assembly

For example, at the beginning of the process for creating a meal plan, nutritional values are set to the maximum allowances for that day. A user might specify that she wants to place a caloric restriction of 2000 calories a day on her meal plan. Recipes must not cause the meal plan to exceed this constraint. This type of restriction is called constraint satisfaction. Each time a recipe is selected, the number of calories in one (or more if multiple servings will be consumed) serving of that food is deducted from those 2000 calories (see Figure 14). Then the next highest meal component for the meal plan is selected by the recognition agent, and the process is repeated. Once the 2000 calorie constraint has been met or all the components have been filled, the process terminates. If a recipe that establishes for the present meal component is not found that will fall within the nutritional restrictions, a set of food items called "single food items" are used. These items are included in the system to "fill in" the meal template if satisfactory recipes cannot be found. The system evaluates the meal plan and looks for missing components and exchanges. If missing items are found, another search through the hierarchy is done to look for single food items that will satisfy the meal and/or nutritional requirements. This is only done however, when a complete search for a particular meal component could not return an applicable recipe. Examples of "single food items" used might include an apple, a dinner roll or a glass of milk.

Rate	Meal Components
1	Dinner Entree
2	Lunch Entree
3	Breakfast Entree
4	Dinner Side
5	Lunch Side
6	Breakfast Side
7	Drink

Breaded Chicken	
Calories	150
Starch	1
Fruit	0
Vegetable	0
Meat	2
Milk	0
Fat	1

Nutrition Information	Total	After Selection
Calories	1500	1350
Starch	7	6
Fruit	3	3
Vegetable	2	2
Meat/Meat Substitute	4	2
Milk	2	2
Fat	4	3

Figure 14 Constraint Satisfaction

The user profile provides the personal and nutritional constraint information for the creation of meal plans. It includes the meals and meal components that the user requires, nutritional requirements the meal plan should satisfy and personal taste preferences of the user. Meal plans are generated in a three part process. This process consists of plan-step generation, assessment and assembly. Plan-step generation is the process of moving through the possible meal components. Plan-step assessment identifies meal components that satisfy the current meal component sought. Plan-step assembly delivers a final meal plan to the user that satisfies both their nutritional and personal taste requirements.

CHAPTER V

SYSTEM RUN TRACES

5.1 Introduction

Meal Planner is a complicated system with many different options available to the user. These options allow the user to personalize the system to produce desirable meal plans. For this to happen, care must be taken when a profile is created. If the questions are hastily answered, less desirable meals may result. More detailed answers give the system more knowledge that is then available to create agreeable meal plans. As the system is used, history information is updated and used to negatively affect the ratings of recipes recently used. Food and component category preferences can also be altered as the system is used. These updates also serve the purpose of expanding the knowledge base so that better recipe selections will be performed.

The following sections include run traces of the system to demonstrate its performance and functionality. Three profiles were used to create a week of meals for each profile. For the each run trace, one day's worth of meals (of the seven days generated) was chosen to be included here. Explanations of the decisions made by the system are given. These meal plans are traced from the beginning to the end of the meal plan generation process. The first of the run traces is from the most simplistic profile. This is one that has no specific nutritional restrictions to be met. Following this profile will allow the examination of the system at a high level without complicating the observations with extra restrictions. The second profile is a person who has vegetarian preferences and wants to restrict her calorie consumption. This run trace will focus on how the system responds to restricted food types and caloric limitations. The final profile includes both calorie and exchange restrictions. While this final profile does not contain any specific food or component category restrictions, it is the most complicated since it is the most nutritionally restricted.

5.2 Run 1: No Restrictions

Profile:

"John" is a 34 year old male. He has never been concerned with what he eats, but finds it difficult to plan what to eat. His profile has no calorie or exchange constraints. He did specify that he does not like any foods that could be categorized as Tomato Based Soup, Lamb, Seafood, Shellfish, Ground Meat, Wild Game, or Pasta with White Sauce. Matching to his meal template is not really important to him, but not repeating recipes, having variability, and staying away from foods and component categories that he does not like is very important. Selecting from his favorite recipes is only a moderate concern. His meal template is composed of the following:

Rate	Meal Component
1	Lunch Entree
2	Starch Snack
3	Breakfast Starch Entree
4	Drink
5	Side
6	Fruit Side
7	Side
8	Drink
9	Side
10	Drink
11	Vegetable Snack
12	Fat
13	Drink
14	Dinner Entree
15	Side
16	Drink

Run 1

****
Meal Component # 1
****
Meal is Lunch
Trying to find a match for Entree
****

Recipes found as matches:

Recipe # 17	Rate: 0.8381 Tomato Mushroom Pasta
Recipe # 89	Rate: 0.8238 Potato Soup
Recipe # 18	Rate: 0.7881 Pesto Linguini
Recipe # 16	Rate: 0.7810 Italian Curry Pasta
Recipe # 34	Rate: 0.7690 Stuffed Fish Fillets
Recipe # 35	Rate: 0.7619 Zucchini Fish Bake
Recipe # 21	Rate: 0.7619 Spanish Chicken
Recipe # 12	Rate: 0.7524 beef
Recipe # 33	Rate: 0.7500 Mushroom-Topped Fillets
Recipe # 25	Rate: 0.7500 Creamy Chicken Dijon
Recipe # 20	Rate: 0.7500 Aloha Chicken
Recipe # 26	Rate: 0.7476 Ramen Chicken
Recipe # 28	Rate: 0.7476 Italian Baked Fish
Recipe # 19	Rate: 0.7310 Vegetable Lasagna
Recipe # 88	Rate: 0.7262 Clam Chowder
Recipe # 27	Rate: 0.7262 Chicken Noodle Casserole
Recipe # 15	Rate: 0.7167 Szechwan Pasta

Selecting: 17 Tomato Mushroom Pasta

There were 17 recipes found to meet John's lunch entrée request. There are a total of 20 entrées available for this selection. Three were excluded because they are tomato based soup recipes that are categorized as one that John does not like. The selected recipe was chosen because of its high rating.

****

Meal Component # 2

****

Meal is Snack/Appetizers

Trying to find a match for Starch

****

Recipes found as matches:

Recipe # 108	Rate: 0.7500 Chicken Salad-Filled Cream Puffs
Recipe # 107	Rate: 0.7262 Potato Skins with Cheese and Bacon

Selecting: 108 Chicken Salad-Filled Cream Puffs

This component was rated second in importance so it is now being filled. There are only two recipes that fit this category. The top rated component is selected and will be excluded if another request for a Starch Snack/Appetizer component is made.

****

Meal Component # 3

****

Meal is Breakfast

Trying to find a match for Starch Entree

****

Recipes found as matches:

Recipe # 24	Rate: 0.8000 Carrot Muffins
Recipe # 9	Rate: 0.7881 Banana Bread
Recipe # 3	Rate: 0.7833 Apple Cider Pancakes
Recipe # 14	Rate: 0.7714 Shredded Wheat Pancakes
Recipe # 23	Rate: 0.7643 Buttermilk Bran Breakfast Squares
Recipe # 22	Rate: 0.7310 Amaretto French Toast

Selecting: 24 Carrot Muffins

There are a total of 13 Breakfast Entrée recipes in the system. Here only six were found to fit John's request for a Starch Entrée for Breakfast.

****

Meal Component # 4

****

Meal is Drink

Trying to find a match for Drink

****

Recipes found as matches:

Recipe # 4	Rate: 0.7881 Frosted Cappuccino
Recipe # 71	Rate: 0.7690 Water
Recipe # 13	Rate: 0.7667 Apple Juice
Recipe # 8	Rate: 0.7643 Apricot-Melon Freeze
Recipe # 7	Rate: 0.7643 Hot Cocoa Mix
Recipe # 6	Rate: 0.7548 Hot Cranberry Cider
Recipe # 5	Rate: 0.7452 Sparkling Punch
Recipe # 1	Rate: 0.7310 Orange Juice
Recipe # 73	Rate: 0.7167 Beer
Recipe # 72	Rate: 0.7119 Wine

Selecting: 4 Frosted Cappuccino

There are 10 Drinks in the system. There was only a general request for a drink. Since no specific specifications were given, any of these drinks could be chosen. In this case, Frosted Cappuccino is selected and inserted into the meal plan.

****
Meal Component # 5
****
Meal is Dinner
Trying to find a match for Side
****

Recipes found as matches:

Recipe # 96	Rate: 0.8024 Pasta with Roasted Peppers and Basil
Recipe # 2	Rate: 0.7881 Oven Fried Parmesan Potatoes
Recipe # 95	Rate: 0.7881 Macaroni and Cheese
Recipe # 76	Rate: 0.7738 Mixed Salad
Recipe # 106	Rate: 0.7714 Grilled Eggplant with Sesame Marinade
Recipe # 75	Rate: 0.7690 Vegetable Medley
Recipe # 97	Rate: 0.7690 Fettuccine Alfredo
Recipe # 103	Rate: 0.7667 Mediterranean Lentil Salad
Recipe # 98	Rate: 0.7643 Spaghetti
Recipe # 99	Rate: 0.7524 Layered Cranberry Applesauce Salad
Recipe # 92	Rate: 0.7524 White Rice
Recipe # 0	Rate: 0.7500 Sautéed Mushrooms
Recipe # 94	Rate: 0.7476 Broccoli Rice
Recipe # 105	Rate: 0.7452 Braised Leeks with Tomatoes
Recipe # 93	Rate: 0.7333 Brown Rice
Recipe # 101	Rate: 0.7286 Grapefruit Salad with Champagne Dressing
Recipe # 10	Rate: 0.7286 Drop Biscuits
Recipe # 102	Rate: 0.7143 Citrus, Fig, and Prosciutto Salad
Recipe # 100	Rate: 0.7143 Five Fruit Salad
Recipe # 104	Rate: 0.7143 Sliced Tomato and Onion Salad
Recipe # 74	Rate: 0.7143 Mixed Vegetables

Selecting: 96 Pasta with Roasted Peppers and Basil

There are 21 recipes that could fit the category of Lunch Side Dish. All of these were found as potential fits to the meal plan. The highest rated component is selected.

****
Meal Component # 6
****
Meal is Breakfast
Trying to find a match for Fruit Side
****

Recipes found as matches:

Recipe # 78	Rate: 0.7667 Fresh Fruit Salad

Selecting: 78 Fresh Fruit Salad

There are a total of eight recipes for Breakfast Side Orders. Only one was found to be applicable here since John wants a Breakfast Side Order that also fits in the Fruit categorization. Since only one recipe was returned as applicable to the current component, it is selected.

****
Meal Component # 7
****
Meal is Breakfast
Trying to find a match for Side
****

Recipes found as matches:

Recipe # 30	Rate: 0.8500 Pineapple Bread
Recipe # 29	Rate: 0.7643 Date Nut Bread
Recipe # 31	Rate: 0.7476 Pumpkin Bread
Recipe # 77	Rate: 0.7333 Hashbrowns
Recipe # 81	Rate: 0.7286 Bacon
Recipe # 82	Rate: 0.7143 Ham
Recipe # 32	Rate: 0.7143 Drop Biscuits

Selecting: 30 Pineapple Bread

Here, a general request for a Breakfast Side order is made. Notice that since component #6 was filled with one of the eight possible Breakfast Side orders, that recipe is not included here as a possible choice to fill this component.

****
Meal Component # 8
****
Meal is Drink
Trying to find a match for Drink
****

Recipes found as matches:

Recipe # 5	Rate: 0.7667 Sparkling Punch
Recipe # 73	Rate: 0.7571 Beer
Recipe # 6	Rate: 0.7548 Hot Cranberry Cider
Recipe # 71	Rate: 0.7524 Water
Recipe # 13	Rate: 0.7500 Apple Juice
Recipe # 8	Rate: 0.7476 Apricot-Melon Freeze
Recipe # 72	Rate: 0.7333 Wine
Recipe # 7	Rate: 0.7286 Hot Cocoa Mix
Recipe # 1	Rate: 0.7143 Orange Juice

Selecting: 5 Sparkling Punch

Here again, notice that the Frosted Cappuccino used to fill meal component #4 is excluded in this list of possible drink selections.

****

Meal Component # 9

****

Meal is Lunch
Trying to find a match for Side

****

Recipes found as matches:

Recipe # 95	Rate: 0.8262 Macaroni and Cheese
Recipe # 97	Rate: 0.8262 Fettuccine Alfredo
Recipe # 105	Rate: 0.8024 Braised Leeks with Tomatoes
Recipe # 76	Rate: 0.7929 Mixed Salad
Recipe # 0	Rate: 0.7881 Sautéed Mushrooms
Recipe # 75	Rate: 0.7881 Vegetable Medley
Recipe # 2	Rate: 0.7881 Oven Fried Parmesan Potatoes
Recipe # 100	Rate: 0.7714 Five Fruit Salad
Recipe # 94	Rate: 0.7667 Broccoli Rice
Recipe # 10	Rate: 0.7667 Drop Biscuits
Recipe # 98	Rate: 0.7643 Spaghetti
Recipe # 102	Rate: 0.7524 Citrus, Fig, and Prosciutto Salad
Recipe # 92	Rate: 0.7524 White Rice
Recipe # 104	Rate: 0.7333 Sliced Tomato and Onion Salad
Recipe # 103	Rate: 0.7286 Mediterranean Lentil Salad
Recipe # 101	Rate: 0.7286 Grapefruit Salad with Champagne Dressing
Recipe # 99	Rate: 0.7143 Layered Cranberry Applesauce Salad
Recipe # 93	Rate: 0.7143 Brown Rice
Recipe # 106	Rate: 0.7143 Grilled Eggplant with Sesame Marinade
Recipe # 74	Rate: 0.6952 Mixed Vegetables

Selecting: 95 Macaroni and Cheese

Here is the first repetitive request for a Lunch or Dinner side. The first request returned 21 potential choices. Here only 20 are given. Also notice, that the recipes ratings are different. This is due to the randomness included in the rating of each recipe.

****

Meal Component # 10

****

Meal is Drink
Trying to find a match for Drink

****

Recipes found as matches:

Recipe # 6	Rate: 0.7738 Hot Cranberry Cider
Recipe # 71	Rate: 0.7524 Water
Recipe # 1	Rate: 0.7524 Orange Juice
Recipe # 73	Rate: 0.7381 Beer
Recipe # 13	Rate: 0.7310 Apple Juice
Recipe # 8	Rate: 0.7286 Apricot-Melon Freeze
Recipe # 7	Rate: 0.7286 Hot Cocoa Mix
Recipe # 72	Rate: 0.6952 Wine

Selecting: 6 Hot Cranberry Cider

With the third request for a drink, only eight recipes are returned as potential choices.

****

Meal Component # 11

****

Meal is Snack/Appetizers
Trying to find a match for Vegetable Casual

****

Recipes found as matches:

No recipes available

No recipes found in the cookbook to match one of the meal components, continuing

Here, there is no available recipe found that meets the requirements for this meal component. The system skips it for now and will return to it later to see if there are any single food items that will meet the requirements for this component.

****

Meal Component # 12

****

Meal is Snack/Appetizers
Trying to find a match for Fat Casual

****

Recipes found as matches:

No recipes available

No recipes found in the cookbook to match one of the meal components, continuing

Again, there is no available recipe found that meets the requirements for this meal component. The system skips it for now and will return to it later to see if there are any single food items that will meet the requirements for this component.

****

Meal Component # 13

****

Meal is Drink
Trying to find a match for Drink

****

Recipes found as matches:

Recipe # 13	Rate: 0.7690 Apple Juice
Recipe # 7	Rate: 0.7667 Hot Cocoa Mix
Recipe # 72	Rate: 0.7524 Wine
Recipe # 73	Rate: 0.7381 Beer
Recipe # 8	Rate: 0.7286 Apricot-Melon Freeze
Recipe # 1	Rate: 0.7143 Orange Juice
Recipe # 71	Rate: 0.6952 Water

Selecting: 13 Apple Juice

Another Drink, only seven recipes were returned.

****

Meal Component # 14

****

Meal is Dinner
Trying to find a match for Entree

****

```
Recipes found as matches:

        Recipe # 16        Rate: 0.8214 Italian Curry Pasta
        Recipe # 89        Rate: 0.8071 Potato Soup
        Recipe # 35        Rate: 0.7833 Zucchini Fish Bake
        Recipe # 21        Rate: 0.7833 Spanish Chicken
        Recipe # 34        Rate: 0.7714 Stuffed Fish Fillets
        Recipe # 33        Rate: 0.7714 Mushroom-Topped Fillets
        Recipe # 20        Rate: 0.7524 Aloha Chicken
        Recipe # 18        Rate: 0.7524 Pesto Linguini
        Recipe # 26        Rate: 0.7500 Ramen Chicken
        Recipe # 12        Rate: 0.7357 beef
        Recipe # 19        Rate: 0.7333 Vegetable Lasagna
        Recipe # 28        Rate: 0.7310 Italian Baked Fish
        Recipe # 15        Rate: 0.7190 Szechwan Pasta
        Recipe # 25        Rate: 0.7143 Creamy Chicken Dijon
        Recipe # 88        Rate: 0.7095 Clam Chowder
        Recipe # 27        Rate: 0.7095 Chicken Noodle Casserole

Selecting: 16  Italian Curry Pasta
```

Here the system is filling the Dinner Entrée. Since all of the recipes in the system that would fulfill the Lunch Entrée category are also categorized to fit the Dinner Entrée category, 16 recipes are returned as potential choices. Recall that 17 recipes were returned when the Lunch Entrée component was filled. One was selected to fill the Lunch Entrée component so there are 16 left and available to fill the Dinner Entrée component.

****

Meal Component # 15

****

Meal is Dinner
Trying to find a match for Side

****

Recipes found as matches:

Recipe # 2	Rate: 0.8262 Oven Fried Parmesan Potatoes
Recipe # 97	Rate: 0.8262 Fettuccine Alfredo
Recipe # 76	Rate: 0.8119 Mixed Salad
Recipe # 75	Rate: 0.7881 Vegetable Medley
Recipe # 98	Rate: 0.7833 Spaghetti
Recipe # 105	Rate: 0.7833 Braised Leeks with Tomatoes
Recipe # 102	Rate: 0.7714 Citrus, Fig, and Prosciutto Salad
Recipe # 100	Rate: 0.7714 Five Fruit Salad
Recipe # 93	Rate: 0.7524 Brown Rice
Recipe # 106	Rate: 0.7524 Grilled Eggplant with Sesame Marinade
Recipe # 74	Rate: 0.7524 Mixed Vegetables
Recipe # 94	Rate: 0.7476 Broccoli Rice
Recipe # 92	Rate: 0.7333 White Rice
Recipe # 0	Rate: 0.7310 Sautéed Mushrooms
Recipe # 103	Rate: 0.7286 Mediterranean Lentil Salad
Recipe # 101	Rate: 0.7286 Grapefruit Salad with Champagne Dressing
Recipe # 10	Rate: 0.7286 Drop Biscuits
Recipe # 99	Rate: 0.7143 Layered Cranberry Applesauce Salad
Recipe # 104	Rate: 0.7143 Sliced Tomato and Onion Salad

Selecting: 2 Oven Fried Parmesan Potatoes

Again, here the system is filling the third Lunch or Dinner Side. As with the Dinner Entrée category, the Dinner Side category also fits the Lunch Side category.

****

Meal Component # 16

****

Meal is Drink
Trying to find a match for Drink

****

Recipes found as matches:

Recipe # 71	Rate: 0.7524 Water
Recipe # 7	Rate: 0.7476 Hot Cocoa Mix
Recipe # 8	Rate: 0.7286 Apricot-Melon Freeze
Recipe # 73	Rate: 0.7190 Beer
Recipe # 72	Rate: 0.7143 Wine
Recipe # 1	Rate: 0.6952 Orange Juice

Selecting: 71 Water

Here, the last component is being filled.

The system will now return to any unfilled components and attempt to fill them with single food items.

****

Filling Component Rated: 12 (Fat Snack/Appetizer)

****

Recipes found as matches:

Recipe # 66	Rate: 0.8667 Pesto Sauce
Recipe # 63	Rate: 0.8667 Avocado
Recipe # 64	Rate: 0.8095 Bacon
Recipe # 43	Rate: 0.7476 Butter
Recipe # 65	Rate: 0.7452 Peanut Butter

Selecting: 66 Pesto Sauce

The system is back to the Fat Snack/Appetizer meal component. It has found five single food items that could satisfy the Fat Snack/Appetizer meal component. It selects the highest rated component.

****

Filling Component Rated: 11 (Vegetable Snack/Appetizer)

****

Recipes found as matches:

Recipe # 49	Rate: 0.8667 Sliced Tomatoes
Recipe # 40	Rate: 0.8476 Carrots
Recipe # 39	Rate: 0.8286 Celery
Recipe # 48	Rate: 0.8095 Snow Peas
Recipe # 51	Rate: 0.7810 Squash
Recipe # 50	Rate: 0.7643 Beets

Selecting: 49 Sliced Tomatoes

The system is back to the Vegetable Snack/Appetizer meal component. It has found six single food items that could satisfy the Vegetable Snack/Appetizer meal component. It selects the highest rated component.

Now that all meal components have been filled, the meal plan is as follows (Note that the meal components are given again):

MEAL PLAN for Day 2

Breakfast:
Breakfast Starch Entree
Carrot Muffins
Breakfast Fruit Side
Fresh Fruit Salad
Breakfast Side
Pineapple Bread
Drink
Sparkling Punch

*Here, a slightly undesirable selection was made. Notice that both the Entrée and the second Side dishes are bread type foods. This will be fixed in the future by the addition of rules to help the system avoid selecting similar components (such as this) within the same meal.

Lunch:
Lunch Entree
Tomato Mushroom Pasta
Lunch Side
Macaroni and Cheese
Drink
Hot Cranberry Cider

*The lunch selections are reasonable, but could possibly benefit from the rules mentioned above since two pasta dishes in the same meal might be undesirable to some people.

Dinner:
Dinner Entree
Italian Curry Pasta
Dinner Side
Oven Fried Parmesan Potatoes
Dinner Side
Pasta with Roasted Peppers and Basil
Drink
Water

*This meal individually is very reasonable. Pasta is again selected as an Entrée. This is mostly because of the limited number of recipes in the system, although the addition of rules as mention earlier would remedy this problem.

Morning Snack:
Starch Snack/Appetizers
Chicken Salad-Filled Cream Puffs
Fat Snack/Appetizers
Pesto Sauce
Drink
Apple Juice

*The lack of recipes is going to cause a lot of repetition in the Snack meal components. Here, the addition of rules would again be helpful in matching single food items to the other meal components for more desirable combinations.

Afternoon Snack:
Vegetable Snack/Appetizers
Sliced Tomatoes
Drink
Frosted Cappuccino

*This Snack is reasonable.

5.3 Run 2: Calorie Limit

Profile:

"Jane" is a 26 year old female. She prefers to stay away from meat and watches her caloric intake. Her profile is restricted to 2000 calories and she has excluded the component classifications of Meat, Poultry, Lamb, Seafood, Shellfish, Beef, Pork, Fish, Ground Meat, and Wild Game. Excluding these recipes and following her calorie restriction is very important. Selecting recipes from her favorite is only moderately important. Matching her meal template and variability in meals is not important to her. Her meal template is composed of the following:

Meal Template:

Rate	Meal Component
1	Breakfast Entree
2	Lunch Entree
3	Snack/Appetizers
4	Dinner Side
5	Snack/Appetizers
6	Breakfast Fruit Side
7	Lunch Vegetable Side
8	Drink
9	Dinner Entree
10	Dinner Side
11	Drink
12	Drink
13	Drink
14	Drink

In this run trace, **calories will be displayed with each recipe.**

Run 2

****

Meal Component # 1

****

Meal is Breakfast

Trying to find a match for Entree

****

Recipes found as matches:

Recipe # 24	Rate: 0.0503 Carrot Muffins	Calories: 163
Recipe # 9	Rate: 0.0421 Banana Bread	Calories: 166
Recipe # 3	Rate: 0.0421 Apple Cider Pancakes	Calories: 144
Recipe # 84	Rate: 0.0421 Cornmeal Mush	Calories: 120
Recipe # 85	Rate: 0.0409 Oatmeal with Raisins	Calories: 120
Recipe # 23	Rate: 0.0378 Buttermilk Bran Breakfast Squares	Calories: 169
Recipe # 80	Rate: 0.0378 Scrambled Eggs	Calories: 120
Recipe # 86	Rate: 0.0296 Orange/Banana Smoothie	Calories: 120
Recipe # 79	Rate: 0.0284 Eggs Benedict	Calories: 200
Recipe # 87	Rate: 0.0284 Strawberry Smoothie	Calories: 120
Recipe # 14	Rate: 0.0253 Shredded Wheat Pancakes	Calories: 129
Recipe # 22	Rate: 0.0190 Amaretto French Toast	Calories: 114

Selecting: 24 Carrot Muffins

Nutrition Info Before Selection:
Calories: 2000
Nutrition Info After Selection:
Calories: 1674

12 out of 13 recipes were returned for the meal component Breakfast Entrée. One was excluded because Jane excluded the Meat meal component category and Recipe #83 is in the Meat category. Once an applicable recipe was found to match the category that also did not exceed the calorie requirements, the nutritional information was updated from 2000 possible calories to 1674 since the recipe has 326 calories. Notice that this profile does not keep track of exchange information.

****
Meal Component # 2
****

Meal is Lunch
Trying to find a match for Entree
****

Recipes found as matches:

Recipe # 27	Rate: 0.0003 Chicken Noodle Casserole Calories: 285
Recipe # 18	Rate: -0.0091 Pesto Linguini Calories: 253
Recipe # 28	Rate: -0.0185 Italian Baked Fish Calories: 142
Recipe # 19	Rate: -0.0185 Vegetable Lasagna Calories: 309
Recipe # 88	Rate: -0.0216 Clam Chowder Calories: 250
Recipe # 90	Rate: -0.0247 Tomato Soup Calories: 175
Recipe # 17	Rate: -0.0247 Italian Curry Pasta Calories: 260
Recipe # 91	Rate: -0.0329 Minestrone Calories: 150
Recipe # 15	Rate: -0.0404 Szechwan Pasta Calories: 147
Recipe # 11	Rate: -0.0454 Tortilla Soup Calories: 77
Recipe # 89	Rate: -0.0466 Potato Soup Calories: 225
Recipe # 16	Rate: -0.0497 Italian Curry Pasta Calories: 260

Selecting: 27 Chicken Noodle Casserole

Nutrition Info Before Selection:
Calories: 1674
Nutrition Info After Selection:
Calories: 1389

Chicken Noodle Casserole was selected for this meal component. Since this recipe is classified as a Casserole dish and not a Poultry dish, it was not excluded as a possible choice. This is satisfactory since Jane only *prefers* to avoid eating meat. If Jane was a strict vegetarian, the recognition agents must be able to recognize these types of problems. To avoid this selection in the future, Jane might input Chicken into the disliked ingredients list. If she does this, any recipe that slips through the establish-refine process will be rated lower by the assembler and consequently have a lower chance of being selected.

****

Meal Component # 3

****

Meal is Snack/Appetizers
Trying to find a match for Casual

****

Recipes found as matches:

Recipe # 107	Rate: 0.0003 Potato Skins with Cheese and Bacon Calories: 106
Recipe # 108	Rate: -0.0216 Chicken Salad-Filled Cream Puffs Calories: 47
Recipe # 110	Rate: -0.0341 Fruit Pizza Calories: 147
Recipe # 109	Rate: -0.0466 Fresh Fruit Calories: 47

Selecting: 107 Potato Skins with Cheese and Bacon

Nutrition Info Before Selection:
Calories: 1389
Nutrition Info After Selection:
Calories: 1283

Here again, notice that a few recipes slipped by that contains meat. These would have to be ruled out by their ingredients. Notice that the available calories continue to be decremented each time a recipe is selected.

****

Meal Component # 4

****

Meal is Dinner

Trying to find a match for Side

****

Recipes found as matches:

Recipe # 96	Rate: -0.0216 Pasta with Roasted Peppers and Basil Calories: 279
Recipe # 98	Rate: -0.0216 Spaghetti Calories: 345
Recipe # 97	Rate: -0.0216 Fettuccine Alfredo Calories: 345
Recipe # 94	Rate: -0.0216 Broccoli Rice Calories: 160
Recipe # 93	Rate: -0.0216 Brown Rice Calories: 250
Recipe # 95	Rate: -0.0310 Macaroni and Cheese Calories: 356
Recipe # 106	Rate: -0.0310 Grilled Eggplant with Sesame Marinade Calories: 58
Recipe # 92	Rate: -0.0341 White Rice Calories: 250
Recipe # 0	Rate: -0.0341 Sautéed Mushrooms Calories: 40
Recipe # 99	Rate: -0.0422 Layered Cranberry Applesauce Salad Calories: 120
Recipe # 101	Rate: -0.0435 Grapefruit Salad with Champagne Dressing Calories: 109
Recipe # 2	Rate: -0.0466 Oven Fried Parmesan Potatoes Calories: 159
Recipe # 103	Rate: -0.0466 Mediterranean Lentil Salad Calories: 254
Recipe # 75	Rate: -0.0497 Vegetable Medley Calories: 80
Recipe # 102	Rate: -0.0547 Citrus, Fig, and Prosciutto Salad Calories: 174
Recipe # 100	Rate: -0.0547 Five Fruit Salad Calories: 81
Recipe # 10	Rate: -0.0560 Drop Biscuits Calories: 165
Recipe # 105	Rate: -0.0672 Braised Leeks with Tomatoes Calories: 62
Recipe # 104	Rate: -0.0685 Sliced Tomato and Onion Salad Calories: 34
Recipe # 74	Rate: -0.0779 Mixed Vegetables Calories: 70
Recipe # 76	Rate: -0.0860 Mixed Salad Calories: 160

Selecting: 96 Pasta with Roasted Peppers and Basil

Nutrition Info Before Selection:
Calories: 1283
Nutrition Info After Selection:
Calories: 1004

****

Meal Component # 5

****

Meal is Snack/Appetizers

Trying to find a match for Casual

****

Recipes found as matches:

Recipe # 108	Rate: -0.0216 Chicken Salad-Filled Cream Puffs Calories: 47	
Recipe # 110	Rate: -0.0560 Fruit Pizza Calories: 147	
Recipe # 109	Rate: -0.0560 Fresh Fruit Calories: 47	

Selecting: 108 Chicken Salad-Filled Cream Puffs

Nutrition Info Before Selection:
Calories: 1004
Nutrition Info After Selection:
Calories: 957

****

Meal Component # 6

****

Meal is Breakfast

Trying to find a match for Fruit Side

****

Recipes found as matches:

Recipe # 78	Rate: -0.0060 Fresh Fruit Salad Calories: 140

Selecting: 78 Fresh Fruit Salad

Nutrition Info Before Selection:
Calories: 957
Nutrition Info After Selection:
Calories: 677

****

Meal Component # 7

****

Meal is Lunch

Trying to find a match for Vegetable Side

****

Recipes found as matches:

Recipe # 2	Rate: -0.0216 Oven Fried Parmesan Potatoes Calories: 159
Recipe # 0	Rate: -0.0341 Sautéed Mushrooms Calories: 40
Recipe # 74	Rate: -0.0404 Mixed Vegetables Calories: 70
Recipe # 76	Rate: -0.0485 Mixed Salad Calories: 160
Recipe # 105	Rate: -0.0547 Braised Leeks with Tomatoes Calories: 62
Recipe # 106	Rate: -0.0560 Grilled Eggplant with Sesame Marinade Calories: 58
Recipe # 104	Rate: -0.0685 Sliced Tomato and Onion Salad Calories: 34
Recipe # 75	Rate: -0.0747 Vegetable Medley Calories: 80

Selecting: 2 Oven Fried Parmesan Potatoes

Nutrition Info Before Selection:
Calories: 677
Nutrition Info After Selection:
Calories: 518

Here, all Lunch or Dinner Sides were eliminated except those that were categorized as Vegetable.

****

Meal Component # 8

****

Meal is Drink

Trying to find a match for Drink

****

Recipes found as matches:

Recipe # 5	**Rate: -0.0122 Sparkling Punch** **Calories: 77**
Recipe # 8	**Rate: -0.0216 Apricot-Melon Freeze** **Calories: 59**
Recipe # 7	**Rate: -0.0341 Hot Cocoa Mix** **Calories: 95**
Recipe # 6	**Rate: -0.0372 Hot Cranberry Cider** **Calories: 129**
Recipe # 72	**Rate: -0.0372 Wine** **Calories: 150**
Recipe # 73	**Rate: -0.0391 Beer** **Calories: 150**
Recipe # 1	**Rate: -0.0404 Orange Juice** **Calories: 112**
Recipe # 13	**Rate: -0.0435 Apple Juice** **Calories: 112**
Recipe # 4	**Rate: -0.0466 Frosted Cappuccino** **Calories: 104**
Recipe # 71	**Rate: -0.0654 Water** **Calories: 0**

Selecting: 5 Sparkling Punch

Nutrition Info Before Selection:
Calories: 518
Nutrition Info After Selection:
Calories: 441

****

Meal Component # 9

****

Meal is Dinner

Trying to find a match for Entree

****

Recipes found as matches:

Recipe # 19	Rate: -0.0279 Vegetable Lasagna Calories: 309
Recipe # 91	Rate: -0.0297 Minestrone Calories: 150
Recipe # 90	Rate: -0.0341 Tomato Soup Calories: 175
Recipe # 11	Rate: -0.0422 Tortilla Soup Calories: 77
Recipe # 18	Rate: -0.0435 Pesto Linguini Calories: 253
Recipe # 88	Rate: -0.0560 Clam Chowder Calories: 250
Recipe # 17	Rate: -0.0591 Italian Curry Pasta Calories: 260
Recipe # 28	Rate: -0.0654 Italian Baked Fish Calories: 142
Recipe # 89	Rate: -0.0685 Potato Soup Calories: 225
Recipe # 16	Rate: -0.0716 Italian Curry Pasta Calories: 260
Recipe # 15	Rate: -0.0872 Szechwan Pasta Calories: 147

Selecting: 19 Vegetable Lasagna

Nutrition Info Before Selection:
Calories: 441
Nutrition Info After Selection:
Calories: 132

****

Meal Component # 10

****

Meal is Dinner

Trying to find a match for Side

****

Recipes found as matches:

Recipe # 93	Rate: 0.2156 Brown Rice Calories: 250
Recipe # 92	Rate: 0.2156 White Rice Calories: 250
Recipe # 103	Rate: 0.2031 Mediterranean Lentil Salad Calories: 254
Recipe # 97	Rate: 0.2031 Fettuccine Alfredo Calories: 345
Recipe # 94	Rate: 0.2031 Broccoli Rice Calories: 160
Recipe # 102	Rate: 0.1825 Citrus, Fig, and Prosciutto Salad Calories: 174
Recipe # 98	Rate: 0.1781 Spaghetti Calories: 345
Recipe # 95	Rate: 0.1688 Macaroni and Cheese Calories: 356
Recipe # 10	Rate: 0.1563 Drop Biscuits Calories: 165
Recipe # 76	Rate: 0.1513 Mixed Salad Calories: 160
Recipe # 99	Rate: -0.0297 Layered Cranberry Applesauce Salad Calories: 120
Recipe # 105	Rate: -0.0297 Braised Leeks with Tomatoes Calories: 62
Recipe # 101	Rate: -0.0310 Grapefruit Salad with Champagne Dressing Calories: 109
Recipe # 104	Rate: -0.0310 Sliced Tomato and Onion Salad Calories: 34
Recipe # 100	Rate: -0.0422 Five Fruit Salad Calories: 81
Recipe # 75	Rate: -0.0497 Vegetable Medley Calories: 80
Recipe # 0	Rate: -0.0591 Sautéed Mushrooms Calories: 40
Recipe # 106	Rate: -0.0685 Grilled Eggplant with Sesame Marinade Calories: 58
Recipe # 74	Rate: -0.0779 Mixed Vegetables Calories: 70

Selecting: 99 Layered Cranberry Applesauce Salad

Nutrition Info Before Selection:
Calories: 132
Nutrition Info After Selection:
Calories: 12

The number of remaining calories is down to 12 here. The system will attempt to fill all remaining components and see if any recipes will satisfy the remaining 12 calories without going over the 2000 calorie restriction.

****

Meal Component # 11

****

Meal is Drink

Trying to find a match for Drink

****

Recipes found as matches:

Recipe # 1	Rate: 0.1969 Orange Juice Calories: 112
Recipe # 13	Rate: 0.1938 Apple Juice Calories: 112
Recipe # 7	Rate: 0.1906 Hot Cocoa Mix Calories: 95
Recipe # 72	Rate: 0.1781 Wine Calories: 150
Recipe # 73	Rate: 0.1763 Beer Calories: 150
Recipe # 6	Rate: 0.1750 Hot Cranberry Cider Calories: 129
Recipe # 8	Rate: 0.1563 Apricot-Melon Freeze Calories: 59
Recipe # 4	Rate: 0.1563 Frosted Cappuccino Calories: 104
Recipe # 71	Rate: -0.0279 Water Calories: 0

Selecting: 71 Water

Nutrition Info Before Selection:
General:
12
Nutrition Info After Selection:
General:
12

Water was found to fill a drink requirement. It has no calories so none were subtracted from the available calories.

****

Meal Component # 12

****

Meal is Drink
Trying to find a match for Drink

****

Recipes found as matches:

Recipe # 13	Rate: 0.2063 Apple Juice Calories: 112
Recipe # 72	Rate: 0.1781 Wine Calories: 150
Recipe # 7	Rate: 0.1781 Hot Cocoa Mix Calories: 95
Recipe # 6	Rate: 0.1750 Hot Cranberry Cider Calories: 129
Recipe # 1	Rate: 0.1719 Orange Juice Calories: 112
Recipe # 73	Rate: 0.1638 Beer Calories: 150
Recipe # 8	Rate: 0.1563 Apricot-Melon Freeze Calories: 59
Recipe # 4	Rate: 0.1563 Frosted Cappuccino Calories: 104

No recipes found that satisfy the nutritional information, continuing

No recipe was found to satisfy this Drink meal component.

****

Meal Component # 13

****

Meal is Drink

Trying to find a match for Drink

****

Recipes found as matches:

Recipe # 7	Rate: 0.2156 Hot Cocoa Mix Calories: 95
Recipe # 13	Rate: 0.2063 Apple Juice Calories: 112
Recipe # 6	Rate: 0.2000 Hot Cranberry Cider Calories: 129
Recipe # 1	Rate: 0.1844 Orange Juice Calories: 112
Recipe # 73	Rate: 0.1763 Beer Calories: 150
Recipe # 8	Rate: 0.1688 Apricot-Melon Freeze Calories: 59
Recipe # 4	Rate: 0.1563 Frosted Cappuccino Calories: 104
Recipe # 72	Rate: 0.1531 Wine Calories: 150

No recipes found that satisfy the nutritional information, continuing

No recipe was found to satisfy this Drink meal component.

****
Meal Component # 14
****
Meal is Drink
Trying to find a match for Drink
****

Recipes found as matches:

Recipe # 7	Rate: 0.2156 Hot Cocoa Mix Calories: 95
Recipe # 13	Rate: 0.2063 Apple Juice Calories: 112
Recipe # 8	Rate: 0.1938 Apricot-Melon Freeze Calories: 59
Recipe # 4	Rate: 0.1938 Frosted Cappuccino Calories: 104
Recipe # 1	Rate: 0.1844 Orange Juice Calories: 112
Recipe # 72	Rate: 0.1781 Wine Calories: 150
Recipe # 73	Rate: 0.1763 Beer Calories: 150
Recipe # 6	Rate: 0.1750 Hot Cranberry Cider Calories: 129

No recipes found that satisfy the nutritional information, continuing

No recipe was found to satisfy this Drink meal component.

MEAL PLAN for Day 2

Breakfast:
Food Breakfast Entree
    Carrot Muffins
Food Breakfast Side Fruit
    Fresh Fruit Salad

This breakfast meal plan would satisfy most people's breakfast expectations and requirements

Lunch:
Food Lunch Entree
    Chicken Noodle Casserole
Food Lunch Side Vegetable
    Oven Fried Parmesan Potatoes
Food Drink
    Water

Lunch here would be very satisfying.

Dinner:
Food Dinner Entree
Vegetable Lasagna
Food Dinner Side
Layered Cranberry Applesauce Salad
Food Dinner Side
Pasta with Roasted Peppers and Basil

There is a small problem here with the selection of two pasta dishes. This combination is satisfactory, but another side might be preferred.

Afternoon Snack:
Food Snack/Appetizers Casual
Potato Skins with Cheese and Bacon
Food Drink
Sparkling Punch

The selection of Potato Skins that have bacon on them is probably not the best choice here, however, adding bacon to the disliked ingredients list should discourage this recipe from being selected in the future.

Evening Snack:
Food Snack/Appetizers Casual
Chicken Salad-Filled Cream Puffs

Here again, the snack contains chicken but the addition of chicken to the disliked ingredients list should fix the problem.

This meal plan is:
12.0 calories under your desired calorie intake.

This meal plan fits Jane's nutritional goals extremely well.

5.4 Run 3: Food Exchanges

Profile:
"Mary" is a 19 year old female. She is extremely health conscious. Her profile has both calorie and exchange constraints. She has restricted her calorie intake to 1500 calories and has chosen the following exchanges:

Exchange	# of Exchanges
Starch	7
Fruit	3
Vegetable	2

Meat	4
Milk	2
Fat	4

She did not have any specific foods or component classifications that she wished to exclude from her meal plans. Matching her diet restrictions and meal template is very important to her. Additionally, selecting recipes that are her favorites is also important. Repetition of recipes and variation are moderately important. Her meal template is composed of the following:

Rate	Meal Component
1	Breakfast Entree
2	Lunch Entree
3	Dinner
4	Breakfast Side
5	Lunch Fruit Side
6	Drink
7	Dinner Side
8	Snack/Appetizers
9	Fruit Snack/Appetizers
10	Drink
11	Drink
12	Dinner Side
13	Drink

In this run-trace, calorie and exchange information will be included after the selected recipe is given. The information before the calories and exchanges for the recipe is given first, followed by the updated information once these values are updated. The "General" information includes Calories and Starch, Fruit, Vegetable, Meat, Milk, and Fat exchanges remaining for the meal plan. Meal values are the Starch, Fruit, Vegetable, Meat, Milk, and Fat exchanges remaining for the current meal such as breakfast.

Run 3

****

Meal Component # 1

****

Meal is Breakfast
Trying to find a match for Entree

****

Recipes found as matches:

Recipe # 23 Rate: 0.3193 Buttermilk Bran Breakfast Squares

Recipe # 22 Rate: 0.3193 Amaretto French Toast

Recipe # 3 Rate: 0.3193 Apple Cider Pancakes

Recipe # 14 Rate: 0.3050 Shredded Wheat Pancakes

Recipe # 9 Rate: 0.3007 Banana Bread

Recipe # 83 Rate: 0.3002 Steak

Recipe # 79 Rate: 0.3002 Eggs Benedict

Recipe # 84 Rate: 0.2912 Cornmeal Mush

Recipe # 80 Rate: 0.2907 Scrambled Eggs

Recipe # 87 Rate: 0.2883 Strawberry Smoothie

Recipe # 24 Rate: 0.2788 Carrot Muffins

Recipe # 85 Rate: 0.2721 Oatmeal with Raisins

Recipe # 86 Rate: 0.2721 Orange/Banana Smoothie

Selecting: 23 Buttermilk Bran Breakfast Squares

Nutrition Info Before Selection:
General:
1500. 7.0 3.0 2.0 4.0 2.0 4.0
Meal:
1.0 1.0 0.0 1.0 1.0 1.0
Nutrition Info After Selection:
General:
1331. 5.0 3.0 2.0 4.0 2.0 4.0
Meal:
-1.0 1.0 0.0 1.0 1.0 1.0

All Breakfast Entrée recipes are returned. All of them fit within the nutritional exchange and calorie restrictions so the top rated one is selected. Calories are subtracted from the total calories. Exchanges are subtracted from both the overall pool of exchanges as well as those allocated for breakfast. Notice that inclusion of this recipe caused the starch exchange value for the meal (Breakfast) to go below 0. This is satisfactory since swapping exchanges between meals is permitted. As long as the overall exchanges are not below –0.5 the meal plan is fine. The Meal exchanges will be used once the meal components are filled as will soon be shown.

****

Meal Component # 2

****

Meal is Lunch
Trying to find a match for Entree

****

Recipes found as matches:

Recipe # 20	Rate: 0.1764	Aloha Chicken
Recipe # 27	Rate: 0.1717	Chicken Noodle Casserole
Recipe # 34	Rate: 0.1579	Stuffed Fish Fillets
Recipe # 25	Rate: 0.1579	Creamy Chicken Dijon
Recipe # 33	Rate: 0.1574	Mushroom-Topped Fillets
Recipe # 19	Rate: 0.1288	Vegetable Lasagna
Recipe # 12	Rate: 0.1288	beef
Recipe # 26	Rate: 0.1240	Ramen Chicken
Recipe # 15	Rate: 0.1102	Szechwan Pasta
Recipe # 17	Rate: 0.1098	Tomato Mushroom Pasta
Recipe # 21	Rate: 0.1074	Spanish Chicken
Recipe # 28	Rate: 0.1074	Italian Baked Fish
Recipe # 35	Rate: 0.1007	Zucchini Fish Bake
Recipe # 11	Rate: 0.1002	Tortilla Soup
Recipe # 16	Rate: 0.1002	Italian Curry Pasta
Recipe # 90	Rate: 0.0955	Tomato Soup
Recipe # 91	Rate: 0.0912	Minestrone
Recipe # 18	Rate: 0.0883	Pesto Linguini
Recipe # 88	Rate: 0.0812	Clam Chowder
Recipe # 89	Rate: 0.0407	Potato Soup

Selecting: 20 Aloha Chicken
Nutrition Info Before Selection:
General:
1331. 5.0 3.0 2.0 4.0 2.0 4.0
Meal:
2.0 1.0 1.0 1.0 0.0 1.0
Nutrition Info After Selection:
General:
1159. 5.0 2.5 2.0 0.5 2.0 4.0
Meal:
2.0 0.5 1.0 -2.5 0.0 1.0

Again, the highest rated recipe does not exceed the nutritional constraints and is selected. Here, the Meat exchange for the meal Lunch falls to –2.5 due to the exchange values of the recipe.

****

Meal Component # 3

****

Meal is Dinner

Trying to find a match for Entree

****

Recipes found as matches:

Recipe # 25	Rate: 0.1102	Creamy Chicken Dijon
Recipe # 88	Rate: 0.0907	Clam Chowder
Recipe # 89	Rate: 0.0883	Potato Soup
Recipe # 18	Rate: 0.0788	Pesto Linguini
Recipe # 27	Rate: 0.0764	Chicken Noodle Casserole
Recipe # 26	Rate: 0.0669	Ramen Chicken
Recipe # 90	Rate: 0.0669	Tomato Soup
Recipe # 17	Rate: 0.0526	Tomato Mushroom Pasta
Recipe # 19	Rate: 0.0526	Vegetable Lasagna
Recipe # 33	Rate: 0.0526	Mushroom-Topped Fillets
Recipe # 91	Rate: 0.0436	Minestrone
Recipe # 21	Rate: 0.0407	Spanish Chicken
Recipe # 16	Rate: 0.0336	Italian Curry Pasta
Recipe # 11	Rate: 0.0336	Tortilla Soup
Recipe # 34	Rate: 0.0245	Stuffed Fish Fillets
Recipe # 15	Rate: 0.0150	Szechwan Pasta
Recipe # 28	Rate: 0.0121	Italian Baked Fish
Recipe # 12	Rate: 0.0050	beef
Recipe # 35	Rate: -0.0136	Zucchini Fish Bake

```
Selecting: 88  Clam Chowder
Nutrition Info Before Selection:
  General:
   1159. 5.0 2.5 2.0 0.5 2.0 4.0
  Meal:
      2.0 0.0 1.0 2.0 1.0 1.0
Nutrition Info After Selection:
  General:
   909. 4.0 2.5 2.0 0.0 1.0 3.0
  Meal:
      1.0 0.0 1.0 1.5 0.0 0.0
```

The highest rated recipe exceeded the nutritional restrictions. It was skipped and the second highest recipe was found to be a match and selected.

****

Meal Component # 4

****

Meal is Breakfast

Trying to find a match for Side

****

```
Recipes found as matches:

  Recipe # 78       Rate: 0.2050  Fresh Fruit Salad

  Recipe # 82       Rate: 0.1860  Ham

  Recipe # 32       Rate: 0.1836  Drop Biscuits

  Recipe # 30       Rate: 0.1769  Pineapple Bread

  Recipe # 29       Rate: 0.1769  Date Nut Bread

  Recipe # 31       Rate: 0.1579  Pumpkin Bread

  Recipe # 77       Rate: 0.1550  Hashbrowns

  Recipe # 81       Rate: 0.1293  Bacon


Selecting: 78  Fresh Fruit Salad
Nutrition Info Before Selection:
  General:
   909. 4.0 2.5 2.0 0.0 1.0 3.0
  Meal:
       -1.0 1.0 0.0 1.0 1.0 1.0
Nutrition Info After Selection:
  General:
   769. 4.0 1.5 2.0 0.0 1.0 3.0
  Meal:
       -1.0 0.0 0.0 1.0 1.0 1.0
```

****

Meal Component # 5

****

Meal is Lunch
Trying to find a match for Fruit Side

****

```
Recipes found as matches:

  Recipe # 100      Rate: 0.0245  Five Fruit Salad

  Recipe # 101      Rate: 0.0150  Grapefruit Salad with Champagne Dressing

  Recipe #  99      Rate: 0.0121  Layered Cranberry Applesauce Salad

  Recipe # 102      Rate: -0.0260  Citrus, Fig, and Prosciutto Salad


Selecting: 100  Five Fruit Salad
Nutrition Info Before Selection:
  General:
   769. 4.0 1.5 2.0 0.0 1.0 3.0
  Meal:
      2.0 0.5 1.0 -2.5 0.0 1.0
Nutrition Info After Selection:
  General:
   688. 4.0 0.5 2.0 0.0 1.0 3.0
  Meal:
      2.0 -0.5 1.0 -2.5 0.0 1.0
```

****

Meal Component # 6

****

Meal is Snack/Appetizer
Trying to find a match for Drink

****

```
Recipes found as matches:

  Recipe #  5    Rate: 0.1193  Sparkling Punch
  Recipe #  6    Rate: 0.1098  Hot Cranberry Cider
  Recipe #  8    Rate: 0.0979  Apricot-Melon Freeze
  Recipe # 71    Rate: 0.0788  Water
  Recipe # 73    Rate: 0.0693  Beer
  Recipe # 13    Rate: 0.0626  Apple Juice
  Recipe #  1    Rate: 0.0626  Orange Juice
  Recipe #  4    Rate: 0.0598  Frosted Cappuccino
  Recipe # 72    Rate: 0.0598  Wine
  Recipe #  7    Rate: 0.0312  Hot Cocoa Mix

Selecting: 71  Water
Nutrition Info Before Selection:
  General:
   688. 4.0 0.5 2.0 0.0 1.0 3.0
  Meal:
       1.0 1.0 0.0 0.0 0.0 1.0
Nutrition Info After Selection:
  General:
   688. 4.0 0.5 2.0 0.0 1.0 3.0
  Meal:
       1.0 1.0 0.0 0.0 0.0 1.0
```

The overall available exchanges for the entire meal plan are getting low. Here, three recipes were passed by before water was chosen to fill this meal component.

****

Meal Component # 7

****

Meal is Dinner
Trying to find a match for Side

****

Recipes found as matches:

Recipe # 2	Rate: 0.0669	Oven Fried Parmesan Potatoes
Recipe # 95	Rate: 0.0621	Macaroni and Cheese
Recipe # 105	Rate: 0.0621	Braised Leeks with Tomatoes
Recipe # 76	Rate: 0.0621	Mixed Salad
Recipe # 75	Rate: 0.0574	Vegetable Medley
Recipe # 96	Rate: 0.0436	Pasta with Roasted Peppers and Basil
Recipe # 92	Rate: 0.0407	White Rice
Recipe # 101	Rate: 0.0340	Grapefruit Salad with Champagne Dressing
Recipe # 10	Rate: 0.0340	Drop Biscuits
Recipe # 104	Rate: 0.0340	Sliced Tomato and Onion Salad
Recipe # 94	Rate: 0.0336	Broccoli Rice
Recipe # 102	Rate: 0.0312	Citrus, Fig, and Prosciutto Salad
Recipe # 93	Rate: 0.0312	Brown Rice
Recipe # 106	Rate: 0.0312	Grilled Eggplant with Sesame Marinade
Recipe # 99	Rate: 0.0217	Layered Cranberry Applesauce Salad
Recipe # 74	Rate: 0.0217	Mixed Vegetables
Recipe # 0	Rate: 0.0150	Sautéed Mushrooms
Recipe # 97	Rate: 0.0145	Fettuccine Alfredo
Recipe # 103	Rate: 0.0098	Mediterranean Lentil Salad
Recipe # 98	Rate: -0.0136	Spaghetti

Selecting: 2 Oven Fried Parmesan Potatoes
Nutrition Info Before Selection:
General:
688. 4.0 0.5 2.0 0.0 1.0 3.0
Meal:
1.0 0.0 1.0 1.5 0.0 0.0
Nutrition Info After Selection:
General:
529. 2.0 0.5 2.0 0.0 1.0 3.0
Meal:
-1.0 0.0 1.0 1.5 0.0 0.0

****

Meal Component # 8

****

Meal is Snack/Appetizers
Trying to find a match for Casual

****

```
Recipes found as matches:

  Recipe # 110     Rate: 0.1288  Fruit Pizza

  Recipe # 107     Rate: 0.1007  Potato Skins with Cheese and Bacon

  Recipe # 109     Rate: 0.0979  Fresh Fruit

  Recipe # 108     Rate: 0.0979  Chicken Salad-Filled Cream Puffs

Selecting: 107  Potato Skins with Cheese and Bacon
Nutrition Info Before Selection:
  General:
   529. 2.0 0.5 2.0 0.0 1.0 3.0
  Meal:
       1.0 0.0 0.0 0.0 0.0 0.0
Nutrition Info After Selection:
  General:
   423. 1.0 0.5 2.0 0.0 1.0 2.0
  Meal:
       0.0 0.0 0.0 0.0 0.0 -1.0
```

****

Meal Component # 9

****

Meal is Snack/Appetizers
Trying to find a match for Fruit Casual

****

```
Recipes found as matches:

  Recipe # 110     Rate: 0.0526  Fruit Pizza

  Recipe # 109     Rate: 0.0121  Fresh Fruit

No recipes found that satisfy the nutritional information, continuing
```

At this point, only 0.5 Fruit exchanges are remaining for the entire meal plan. Both of these recipes require 1 Fruit exchange.

****

Meal Component # 10

****

Meal is Breakfast
Trying to find a match for Drink

****

Recipes found as matches:

Recipe # 5	Rate: 0.1193	Sparkling Punch
Recipe # 6	Rate: 0.1193	Hot Cranberry Cider
Recipe # 7	Rate: 0.0979	Hot Cocoa Mix
Recipe # 1	Rate: 0.0912	Orange Juice
Recipe # 13	Rate: 0.0721	Apple Juice
Recipe # 8	Rate: 0.0312	Apricot-Melon Freeze
Recipe # 4	Rate: 0.0312	Frosted Cappuccino
Recipe # 73	Rate: 0.0217	Beer
Recipe # 72	Rate: -0.0069	Wine

Selecting: 7 Hot Cocoa Mix
Nutrition Info Before Selection:
General:
423. 1.0 0.5 2.0 0.0 1.0 2.0
Meal:
-1.0 0.0 0.0 1.0 1.0 1.0
Nutrition Info After Selection:
General:
328. 1.0 0.5 2.0 0.0 0.0 2.0
Meal:
-1.0 0.0 0.0 1.0 0.0 1.0

****

Meal Component # 11

****

Meal is Lunch

Trying to find a match for Drink

****

Recipes found as matches:

Recipe # 5	Rate: 0.1098	Sparkling Punch
Recipe # 6	Rate: 0.1002	Hot Cranberry Cider
Recipe # 1	Rate: 0.0912	Orange Juice
Recipe # 13	Rate: 0.0817	Apple Juice
Recipe # 8	Rate: 0.0312	Apricot-Melon Freeze
Recipe # 72	Rate: 0.0217	Wine
Recipe # 4	Rate: 0.0121	Frosted Cappuccino
Recipe # 73	Rate: 0.0026	Beer

Selecting: 72 Wine
Nutrition Info Before Selection:
General:
328. 1.0 0.5 2.0 0.0 0.0 2.0
Meal:
2.0 -0.5 1.0 -2.5 0.0 1.0
Nutrition Info After Selection:
General:
178. 0.0 0.5 2.0 0.0 0.0 2.0
Meal:
1.0 -0.5 1.0 -2.5 0.0 1.0

****

Meal Component # 12

****

Meal is Dinner

Trying to find a match for Side

****

Recipes found as matches:

Recipe # 97	Rate: 0.2095	Fettuccine Alfredo
Recipe # 103	Rate: 0.1952	Mediterranean Lentil Salad
Recipe # 95	Rate: 0.1810	Macaroni and Cheese
Recipe # 98	Rate: 0.1433	Spaghetti
Recipe # 92	Rate: 0.1405	White Rice
Recipe # 96	Rate: 0.1338	Pasta with Roasted Peppers and Basil
Recipe # 93	Rate: 0.1310	Brown Rice
Recipe # 76	Rate: 0.0621	Mixed Salad
Recipe # 101	Rate: 0.0436	Grapefruit Salad with Champagne Dressing
Recipe # 10	Rate: 0.0436	Drop Biscuits
Recipe # 104	Rate: 0.0436	Sliced Tomato and Onion Salad
Recipe # 94	Rate: 0.0431	Broccoli Rice
Recipe # 106	Rate: 0.0407	Grilled Eggplant with Sesame Marinade
Recipe # 105	Rate: 0.0336	Braised Leeks with Tomatoes
Recipe # 75	Rate: 0.0288	Vegetable Medley
Recipe # 102	Rate: 0.0217	Citrus, Fig, and Prosciutto Salad
Recipe # 0	Rate: 0.0150	Sautéed Mushrooms
Recipe # 99	Rate: 0.0121	Layered Cranberry Applesauce Salad
Recipe # 74	Rate: 0.0026	Mixed Vegetables

Selecting: 76 Mixed Salad
Nutrition Info Before Selection:
General:
178. 0.0 0.5 2.0 0.0 0.0 2.0
Meal:
-1.0 0.0 1.0 1.5 0.0 0.0
Nutrition Info After Selection:
General:
18. 0.0 0.5 1.0 0.0 0.0 1.0
Meal:
-1.0 0.0 0.0 1.5 0.0 -1.0

The eighth recipe was finally selected here. There are very few exchanges left for the meal plan so selection of a recipe is becoming harder.

****
Meal Component # 13
****

Meal is Dinner
Trying to find a match for Drink
****

Recipes found as matches:

Recipe # 5	Rate: 0.2381	Sparkling Punch
Recipe # 6	Rate: 0.2190	Hot Cranberry Cider
Recipe # 1	Rate: 0.2005	Orange Juice
Recipe # 13	Rate: 0.1814	Apple Juice
Recipe # 8	Rate: 0.1500	Apricot-Melon Freeze
Recipe # 4	Rate: 0.1405	Frosted Cappuccino
Recipe # 73	Rate: 0.1119	Beer

No recipes found that satisfy the nutritional information, continuing

None of the recipes for this meal component were able to satisfy the remaining nutritional requirements. This component is skipped. Being the last meal component to fill, Meal Planner will now attempt to fill any empty meals with single food items to satisfy the empty meals exchanges.

Afternoon Snack Empty
****

Meal: Afternoon Snack
****

The following exchanges are needed

Need 1.0 Starch Exchanges
0.0 Starch Exchanges Left for Entire Meal

Recipes found as matches:

Recipe # 70 Rate: 0.2762 English Muffin

Recipe # 67 Rate: 0.2667 Beans

Recipe # 44 Rate: 0.2667 Toast

Recipe # 69 Rate: 0.2571 Bagel

Recipe # 68 Rate: 0.2476 Corn

Recipe # 36 Rate: 0.2190 Packaged Rolls

No Recipe Found To Match Nutritional Requirements!

This meal contains nothing but water. There is 1 Starch exchange allocated to this meal so Meal Planner attempts to fill it. Recipes are found, but there are no remaining starch exchanges allowed for the meal plan so none of the recipes are selected. The starch exchange from this meal was given to another meal. Afternoon Snack was the only empty meal so now Meal Planner tries to satisfy any remaining exchanges for the meals so that all nutritional constraints are satisfied. The following is a list of remaining nutritional information. It includes the remaining calories and exchanges for the meal plan as well as a list of the meals with their current available corresponding exchanges.

Calories: 18

	Total	Breakfast	Lunch	Dinner	Afternoon Snack	Evening Snack
Starch:	0.0	-1.0	1.0	-1.0	1.0	0.0
Fruit:	0.5	0.0	-0.5	0.0	1.0	0.0
Veg.:	1.0	0.0	1.0	0.0	0.0	0.0
Meat:	0.0	1.0	-2.5	1.5	0.0	0.0
Milk:	0.0	0.0	0.0	0.0	0.0	0.0
Fat:	1.0	1.0	1.0	-1.0	1.0	-1.0

Meal Planner now checks each of the six exchanges for remaining exchanges and tries to fill them beginning with the meal with the most exchanges remaining.

****
Lunch Has The Most Starch Remaining, Adding A Starch
****
There are no more Starch exchanges available for the meal

Lunch is found to have the most Starch exchanges left, but it is found that there are no remaining Starch exchanges for the meal plan.

****
Afternoon Snack Has The Most Fruit Remaining, Adding A Fruit
****

Need 1.0 Fruit Exchanges
0.5 Fruit Exchanges Left for Entire Meal

```
Recipes found as matches:

  Recipe # 38        Rate: 0.2762  Orange
  Recipe # 57        Rate: 0.2476  Peach
  Recipe # 55        Rate: 0.2476  Mandarin Oranges
  Recipe # 37        Rate: 0.2476  Banana
  Recipe # 54        Rate: 0.2381  Cantaloupe
  Recipe # 53        Rate: 0.2381  Mango
  Recipe # 56        Rate: 0.2286  Cherries
  Recipe # 52        Rate: 0.2286  Blackberries

No Recipe Found To Match Nutritional Requirements!
```

Afternoon Snack has the most remaining Fruit exchanges. Recipes are found but none that have only 0.5 Fruit exchanges.

****

Lunch Has The Most Vegetables Remaining, Adding A Vegetable

****

Need 1.0 Vegetable Exchanges
1.0 Vegetable Exchanges Left for Entire Meal

```
Recipes found as matches:

  Recipe # 48        Rate: 0.2762  Snow Peas

  Recipe # 49        Rate: 0.2667  Sliced Tomatoes

  Recipe # 40        Rate: 0.2476  Carrots

  Recipe # 39        Rate: 0.2476  Celery

  Recipe # 51        Rate: 0.2286  Squash

  Recipe # 50        Rate: 0.2262  Beets


Selecting: 48  Snow Peas

Nutrition Info Before Selection:
  General:
    18. 0.0 0.5 1.0 0.0 0.0 1.0
  Meal:
       1.0 -0.5 1.0 -2.5 0.0 1.0

Nutrition Info After Selection:
  General:
   -22. 0.0 0.5 0.0 0.0 0.0 1.0
  Meal:
       1.0 -0.5 0.0 -2.5 0.0 1.0
```

A recipe is found that satisfies the one remaining Vegetable exchange. It is added to Lunch since lunch has more remaining Vegetable exchanges than any other meal.

Meat and Milk exchanges are satisfied for the meal plan so no search is conducted.

****
Breakfast Has The Most Fat Remaining, Adding A Fat
****

Need 1.0 Fat Exchanges
1.0 Fat Exchanges Left for Entire Meal

```
Recipes found as matches:

  Recipe # 65        Rate: 0.2262  Peanut Butter

  Recipe # 64        Rate: 0.2195  Bacon

  Recipe # 66        Rate: 0.2100  Pesto Sauce

  Recipe # 63        Rate: 0.2071  Avocado

  Recipe # 43        Rate: 0.2000  Butter

Selecting: 65  Peanut Butter

Nutrition Info Before Selection:
  General:
   -22. 0.0 0.5 0.0 0.0 0.0 1.0
  Meal:
     - 1.0 0.0 0.0 1.0 0.0 1.0

Nutrition Info After Selection:
  General:
   -67. 0.0 0.5 0.0 0.0 0.0 0.0
  Meal:
     - 1.0 0.0 0.0 1.0 0.0 0.0
```

One Fat exchange is needed. Peanut Butter is selected and added to Breakfast.

MEAL PLAN

Breakfast:
  Breakfast Entree
    Buttermilk Bran Breakfast Squares
  Breakfast Side
    Fresh Fruit Salad
  Drink
    Hot Cocoa Mix
  Added
    Peanut Butter

Lunch:
Lunch Entree
Aloha Chicken
Lunch Fruit Side
Five Fruit Salad
Drink
Wine
Added
Snow Peas

Dinner:
Dinner Entree
Clam Chowder
Dinner Side
Mixed Salad
Dinner Side
Oven Fried Parmesan Potatoes

Afternoon Snack:
Drink
Water

Evening Snack:
Food Snack/Appetizers
Potato Skins with Cheese and Bacon

This meal plan is:
67.0 calories over your desired calorie intake.
Starch exchanges are fulfilled.
0.5 exchanges under your desired Fruit exchanges
Vegetable exchanges are fulfilled.
Meat exchanges are fulfilled.
Milk exchanges are fulfilled.
Fat exchanges are fulfilled.

This meal plan satisfies all but 1exchange. It is 0.5 exchanges short of the desired Fruit exchange which is the allowable variation within the system. The meal plan is also 67 calories over the desired caloric intake which is also within the allowable variation of the system.

Overall, the system performs reasonably well. It is able to generate meal plans that are tailored to the users expectations of a meal plan. The generated meal plans created contain reasonable meals that match the user's tastes and offer variety, while maintaining the user's nutritional requirements.

CHAPTER VI

CONCLUSIONS

6.1 Conclusion

This thesis introduced nutritional meal planning as a problem and demonstrated the utility of a Generic Task routine decision making algorithm as a solution to this problem. Nutritional meal planning is a difficult problem that is a prime candidate for artificial intelligence research. The problem involves a large knowledge base. This must consist of a large amount of both personal preferences and constraints, as well as nutritional preferences and constraints, and the foods and recipes (including their nutritional information) from which the eventual meal plan will be created. This information is necessary to produce meal plans that are useful to the user. This problem depends highly on user input. The more information Meal Planner has about the likes, dislikes, and meal expectations of the user, the better the meal plans are at matching the user's expectations.

The decision making part of nutritional meal planning involves the selection of foods and recipes from the available foods and recipes to fill the desired meal components while maintaining the personal and nutritional preferences and constraints of the user. This process is highly dependent on the specifications given by the user when a profile is created. Selection of recipes and foods to fill the meal plan is extremely difficult due to the vast number of possible choices of recipes and foods from which a meal plan can be created. User information helps eliminate some of the choices, but the information must be organized in a way that this information can be efficiently used to find a solution.

The Generic Task routine decision making algorithm is a natural solution to this problem. Although not impossible, the large scope of this problem would make it extremely difficult to implement using rules or case based reasoning as discussed in chapter 2. The routine decision making algorithm provides an efficient and effective way to organize and maintain the knowledge of this system. It also provides an effective way to use the knowledge obtained from the user (such as the personal and nutritional preferences and constraints) to reduce the search space of possible choices and transform this intractable search problem into a tractable one.

The goal for Meal Planner is to create a meal plan for a user that satisfies that user's nutritional and personal preferences and constraints. Sub-goals consist of desired meal components specified by the user along with the associated preferences and constraints that might apply. These sub-goals are created with knowledge of previous meals the user has enjoyed.

The routine decision making algorithm calls on the fundamental Generic Tasks necessary for routine decision making, Hierarchical Classification, Hypothesis Matching and Abductive Assembly. Variations of these tasks form the basis for this algorithm. These are Plan-Step Generation, Plan-Step Assessment, and Plan-Step Assembly. For the nutritional planning problem, Plan-Steps are the classifications of the foods and recipes themselves. These Plan-Steps are organized into categorization levels from abstract to concrete, ranging from "food" to specific recipe names. This organization allows for convenient access to specific recipe categories and efficient search through the search space of Plan-Steps during Plan-Step Generation.

Recognition agents are used at each node to determine if a particular node is applicable to the current sub-goal. The recognition agents in Meal Planner perform the task of determining which nodes satisfy certain sub-goals. They also exclude nodes that have been used previously in the meal so that no repetition is seen within a meal. Plan-Step Assessment has also been successfully implemented. Each recipe returned by the recognition agents through Plan-Step Generation is assessed to see how applicable it is to the sub-goal compared to all other recipes returned. This assessment is based on six decision making attributes. Each attribute is considered in two different ways. The user rates, on a scale of 1-5, each attribute based on how important each attributes is. The attributes are then compared to the recipe. The recipe is then given a rating as to how well a particular recipe fits each attribute. These two ratings are then combined to produce a final rating for the given recipe. This method works well to discourage recipes that might not be desirable selections to fulfill the final goal. It also provides variability while allowing the user to specify how much variability since half of the assessment is based on user input.

Plan-Step Assembly takes the rated recipes and selects the one with the highest rating. It then determines if the selected recipe will meet the nutritional constraints imposed by the user. If it does, the recipe is inserted into the meal plan and the nutritional information is updated in the system. If the recipe exceeds the user's nutritional constraints it is discarded. The Assembler then attempts to find another recipe that will satisfy the users nutritional constraints by selecting the next highest rated recipe, comparing it's nutritional information with the remaining nutritional components available for the meal plan. It continues this process until a recipe is found or there are no remaining applicable recipes. If a recipe is still not found, the current meal component is skipped until all other meal components are filled or skipped. The Assembler will then return to any skipped meal components and attempt to satisfy the remaining nutritional information (exchanges and calories) for the meal.

Meal Planner has successfully solved the nutritional meal planning problem. Meal plans created are reasonable and the solutions are created efficiently. Nutritional goals are met by the meal plans created by Meal Planner within reasonable bounds, ±200 calories and ±0.5 exchanges, if these constraints are placed upon the system. Personal preferences are also met. Disliked foods are successfully eliminated as potential meal component choices to allow for selection of preferred foods.

The use of the routine decision making algorithm has proved to be an effective solution to the nutritional meal planning problem. The successful use of this algorithm in Shopper and Routine Scheduler for solutions to the consumer and scheduling problems, added to the implementation of Meal Planner, demonstrates the utility of this algorithm to many problem domains. The routine decision making algorithm is a versatile algorithm that can be applied to any decision making problem where agent actions can be represented as pre-enumerated knowledge. This knowledge is then used by the agents to find solutions to decision making problems. In addition to this knowledge, the problem must also contain a mechanism to match the agents needs to the actions available and a mechanism for evaluation of the utility of each action.

6.2 Problems With Meal Planner

While most of the final meal plans created by Meal Planner are within reasonable bounds, there are a few problems seen within the process of Plan-Step Assembly. A majority of the repetition seen in the meal plans created is due to the limited amount of recipes available for the system to select from. As the recipe base is expanded, this repetition will be reduced. Expansion of the recipe base will also allow more fine tuned nutritional constraints. Limitations in the number of recipes also cause problems when exchanges are being used as a nutrition guideline. With limited recipes, the system sometimes has trouble finding sub-goal solutions which leads to less favorable meal plans. A database of 500-1000 recipes, distributed among all desired meal component categories would be a sufficient amount to produce the variability desired.

Other problems are also seen. The meal plans created sometimes contain undesirable combinations of foods or repetition in the types of foods, such as multiple pasta dishes, within the same day or same meal. This problem can be remedied fairly easily with the addition of rules to discourage these types of combinations.

Another problem is currently seen when the user gives very general information. This is because the system has a less defined idea of the expectations of the user leading to the creation of less desirable meal plans. An example of this is if a general Side Order is requested multiple times in a meal, the meal plan might contain two similar side items that might be less desirable than two different side items. A solution to allow for general information to be given will be discussed shortly. If given detailed information, the system performs better when meal plans are generated. For the most part, the meal plans are desirable to the user. There are a couple key points that need to be addressed with the Plan-Step Assembly process. When general information is given, such as Dinner Entree verses Meat Dinner Entree, more variation is seen because fewer meal component categories are excluded from the system producing more recipes from which to select. This is good from a variability standpoint since in meal planning it might not be desirable to have the same Dinner Entree every night. From a performance efficiency standpoint, generality could be unfavorable when the amount of recipes in the system becomes large because the search for recipes is over a greater space of possible recipes, taking more time.

Certain cases also cause the desirability of the final meal plans to decline when general information is given. This is seen when insufficient information is given and a meal component category that is not applicable to the sub-goal is established. Consequently, there is no available information for its recognition agent to determine that it should *not* be established. An example of this is a meal plan that has beer for breakfast. Most people would find beer for breakfast undesirable (although some might encourage this selection). Since someone might want beer for breakfast, it cannot automatically be excluded. If a user does not specify that she does not desire a beverage containing alcohol for breakfast, there is a possibility that an alcoholic beverage will be selected. This problem is due to the closed world assumption [Reiter, 1978]. This assumption is necessary to create a solution for problem solving. When information is left out, it is assumed to be false so any assumptions must be made using only available information. Data inference (a Generic Task) [Mittal *et al* 1984] could be used to apply common sense rules like "Beer for breakfast is unusual but not unheard of". Similarly, data inference can be used to identify foods that are variations of the same type of dish as a solution to this problem. This problem can be solved by expanding the knowledge of the recognition agents to perform inference on each node. They could then identify variations of already selected food items and rule them out.

Although the system requires a significant amount of interaction with the user while it is gathering the information it needs to create meal plans, most of this information is gathered when the user creates a profile which only needs to be done once. Creating the profile is slightly time consuming, but not overbearing. Once it is done, the user does not need to repeat the process unless changes to the profile are desired. The system can be "fine tuned" by the user as it is used by maintaining the recipes' favorite ratings. Maintaining a list of disliked foods also allows the user to mold the system to her personal likes and dislikes. Multiple profiles can also be used to vary meal components. There are many things that can be done to make the system work even better. Some of these are discussed in the next section. Overall, the system performs reasonably well. There is variation in the meal plans, which are catered to the person they are created for. The Generic Task routine decision making algorithm proved to be an excellent solution to the difficult problem of nutritional meal planning. With a few expansions in the knowledge available to the system, the reasonable meal plans now generated will become excellent ones.

6.3 Future Work

There are many things that can be done to this system to "fine tune" its results and make it easier and less time consuming to use. These expansions of the current system are planned to be implemented in the near future. As mentioned earlier, the implementation of rules will be essential to the system to assure some general combinations do not occur, such as having multiple pasta dishes in the same meal. As meal plans are created, a mechanism for the user to identify "good" and "bad" food combinations should also exist. This will allow the user to personalize selections and assure desirable results in the final meal plans. This can be implemented so that rules are made that discourage or encourage certain food combinations when specified by the user.

The secondary goal of this system is to allow flexibility for the user. The user should be able to be as general or specific as she would like and still get meal plans that satisfy her requirements. The system should also be expanded to allow for multiple meal templates. Now, a complete profile must be made if additional meal templates are desired. This is time consuming and not very practical. Also, an expansion to allow the user to create one meal or a week of meals would also be useful. This will save the user time since she will be able to create as much or as little as she desires. The user should also be allowed to partially fill in a meal plan and have the system fill in the rest so that the entire meal still satisfies the user's nutritional requirements. Along the same lines, the user will also be able to replace foods and recipes in the created meal plan with alternative recipes that have similar nutritional values, if a meal component is filled with an undesirable food or combination of foods.

A database will be created to store the recipes and profiles. This will allow for easier maintenance and access to this knowledge. The user will be given more flexibility to change her profile or favorite ratings for the recipes. For now, the favorite ratings are static and do not change between users. This should not be the case in the final version of this system. A GUI will also be created to allow for easier user/system interaction. The data input in the text based program can become tedious. A GUI will greatly decrease the amount of time the user needs to spend with the system as well as increase the ease of use.

Finally, the system will be expanded to handle multiple person meal plans. This will be difficult to implement since each person will have her own personal and nutritional preferences and constraints. The meals plans will have to be created in a way that fulfills all the members' preferences and needs. This will involve creating a meal plan for the person in the household who has the most restrictive diet, and then adding to other family members' meal plans so that their nutritional needs are also met. The evaluation process will be expanded to include considerations of all family members' food preferences. Consequently, everyone contributes equally in the food preference ratings. When coupled with the randomness rating, this will result in satisfying everyone with the meals they prefer at some time. This process, where each person will contribute equally to the rating, will involve an evaluation similar to the way each attribute contributes in the recipe rating. Expanding the system to include family nutritional meal planning will allow it to provide a wider, more useful service to a broader range of users.

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APPENDIX A

NUTRITION INFORMATION DESCRIPTIONS

The following provides a brief overview of the nutritional information used in Meal Planner.

A.1 Height and Weight Charts

The 1983 Metropolitan Life Insurance Company height-weight table [Metropolitan Life insurance Company, 1983; Lee and Nieman, 1996] was used in Meal Planner. This table includes both male and female information. Height and frame size is used to index the table and determine a recommended weight range for the person. Elbow Breadth is used to determine frame size is used. This technique is the one used when the height/weight table was created and therefore, the recommended method when using this table. This technique involves measuring the breadth of the elbow while the subject stands erectly. The right arm is extend outward until it is perpendicular to the body. The arm is then bent until a 90° angle is formed with the elbow. Calipers are then used to measure the widest part of the elbow to the nearest 1/8 inch. The user must do the measurement of frame size if recommendations on weight are to be made.

A.2 Caloric Intake Calculations

Minimum caloric intake is commonly measured using an equation to calculate bodies energy expenditure. There are several different variations to these equations but the ones described here were chosen to be used in Meal Planner. There are two parts to this calculation. The first equation used is the Harris-Benedict equation for calculating resting energy expenditure (REE) [Lee and Nieman, 1996]. This represents the number of calories a persons body uses in a day without any physical activity whatsoever. Added to this value, is an adjustment made based on the activity level of the person. The less active a person is, the fewer calories will be added to the REE value.

A.3 Exchange Restrictions

In 1992, the USDA released a new food guide called the Food Guide Pyramid [Lee and Nieman, 1996]. This pyramid was a graphical representation of the foods people should eat. The pyramid is sectioned into six parts. The size of the section represents the amount of that type of food a person should eat. Along with these sections, a serving amount is given for each of the sections. This gives a person a guideline to follow when planning meals.

A guide that was developed much earlier (1950) is the Exchange System. The American Dietetic Association and the American Diabetes Association in cooperation with the US Public Health Service developed this system. It categorizes food into carbohydrate, meat and fat. The carbohydrate category is then separated into fruit, starch, milk, and vegetable yielding six food categories in all. Each of these categories is then associated with a set number of exchanges (can also be thought of as servings) for each category. An exchange list was then published along with the nutritional guideline for what a particular category consists. For example, 1 cup of skim milk is a milk exchange. If a milk product is absent from the exchange list, an approximation of 1 exchange of this food can be made because 1 milk exchange is also defined as 12 grams of carbohydrate and 8 grams of protein [American Diabetes Association, Inc. and the American Dietetic Association, 1995].

Eli Lilly and Company print a meal planning pamphlet [Eli Lilly and Company, 1997] that uses the exchange guidelines to aid diabetes patients in following a healthier eating plan. An exchange list is provided as well as a list of daily exchanges for certain caloric intake levels (see Figure 15). A graphical representation similar to the Food Guide Pyramid is used to represent the food categories and allowable exchanges (see Figure 16). This information was used as a basis for the recommended exchange intake. A set of exchanges is chosen based on a calculated or input caloric intake required by the user.

	1200	1500	1800	2000	2500
Starch	5	7	8	9	11
Fruit	3	3	4	4	6
Milk	2	2	3	3	3
Veg.	2	2	3	4	5
Meat	4	4	6	6	8
Fat	3	4	4	5	6

Figure 15 Exchange Allocations Based on Total Caloric Intake*

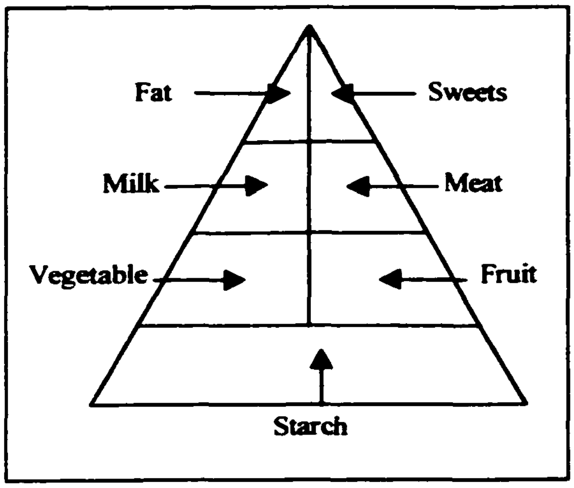

Figure 16 Food Categories*

*Adapted from Daily Meal Planning Guide. (1997). Eli Lilly and Company.

APPENDIX B

RECIPES

This section lists all the recipe names and nutrition information that are currently in the system. The first line is the recipe name. The second line of numbers lists:

Calories/Serving
Exchanges in the following order:
- Starch
- Fruit
- Vegetable
- Meat
- Milk
- Fat

The last line lists the categories that this recipe meets the requirements for in the hierarchy.
For Example, using the first recipe as an example:

Sautéed Mushrooms
40 0.00 0.00 1.00 0.00 0.00 1.00
Food Lunch/Dinner Take Side Prep>1 Vegetable

There are:
- 40 Calories/Serving
- 0 Starch Exchanges
- 0 Fruit Exchanges
- 1 Vegetable Exchange
- 0 Meat Exchanges
- 0 Milk Exchanges
- 1 Fat Exchange

It can satisfy a lunch or dinner vegetable side component that can be taken out and made in less than 1 hour.

Note: Some nutrition information was not available so it was approximated for the purpose of testing the system.

Sautéed Mushrooms
40 0.00 0.00 1.00 0.00 0.00 1.00
Food Lunch/Dinner Take Side Prep>1 Vegetable

Orange Juice
112 0.00 1.00 0.00 0.00 0.00 0.00
Food Drink Non-Dairy No-Alcohol Any-Time

Oven Fried Parmesan Potatoes
159 2.00 0.00 0.00 0.00 0.00 0.00
Food Lunch/Dinner Eat-in Side Prep1/2-1 Vegetable

Apple Cider Pancakes
144 2.00 0.00 0.00 0.00 0.00 0.00
Food Breakfast Eat-in Entree Prep<1/2 Starch

Frosted Cappuccino
104 0.00 0.00 0.00 0.00 1.00 0.00
Food Drink Dairy No-Alcohol Breakfast

Sparkling Punch
77 0.00 1.00 0.00 0.00 0.00 0.00
Food Drink Non-Dairy No-Alcohol Any-Time

Hot Cranberry Cider
129 0.00 1.00 0.00 0.00 0.00 0.00
Food Drink Non-Dairy No-Alcohol Snack

Hot Cocoa Mix
95 0.00 0.00 0.00 0.00 1.00 0.00
Food Drink Dairy No-Alcohol Any-Time

Apricot-Melon Freeze
59 0.00 1.00 0.00 0.00 0.00 0.00
Food Drink Non-Dairy No-Alcohol Snack

Banana Bread
166 2.00 0.00 0.00 0.00 0.00 0.00
Food Breakfast Take Entree Prep1/2-1 Starch

Drop Biscuits
165 2.00 0.00 0.00 0.00 0.00 0.50
Food Lunch/Dinner Eat-in Side Prep<1/2 Starch

Tortilla Soup
77 0.50 0.00 1.00 0.00 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Soup/Stew TomatoBase

Beef
120 0.00 0.00 0.00 2.00 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Meat Beef 12

Apple Juice
112 0.00 1.00 0.00 0.00 0.00 0.00
Food Drink Non-Dairy No-Alcohol Any-Time

Shredded Wheat Pancakes
129 1.00 1.00 0.00 0.00 0.00 0.00
Food Breakfast Eat-in Entree Prep1/2-1 Starch

Szechwan Pasta
147 1.50 0.00 0.50 0.00 0.00 0.50
Food Lunch/Dinner Eat-in Entree Prep<1/2 Pasta

Italian Curry Pasta
260 2.00 0.00 3.50 0.00 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Pasta

Italian Curry Pasta
260 2.00 0.00 3.50 0.00 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Pasta

Pesto Linguini
253 2.50 0.00 0.00 0.00 0.00 1.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Pasta

Vegetable Lasagna
309 2.50 0.00 3.00 0.50 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep1/2-1 Vegetarian

Aloha Chicken
172 0.00 0.50 0.00 3.50 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Meat Poultry

Spanish Chicken
147 0.00 0.00 1.00 3.50 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Meat Poultry

Amaretto French Toast
114 1.00 0.00 0.00 0.00 0.00 0.00
Food Breakfast Eat-in Entree Prep<1/2 Starch

Buttermilk Bran Breakfast Squares
169 2.00 0.00 0.00 0.00 0.00 0.00
Food Breakfast Eat-in Entree Prep1/2-1 Starch

Carrot Muffins
163 2.00 0.00 0.00 0.00 0.00 0.00
Food Breakfast Eat-in Entree Prep1/2-1 Starch

Creamy Chicken Dijon
318 2.00 0.00 1.00 3.50 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Meat Poultry

Chicken Noodle Casserole
285 2.50 0.00 0.00 2.50 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Casserole

Italian Baked Fish
142 0.50 0.00 0.00 3.50 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Meatless

Date Nut Bread
156 2.00 0.00 0.00 0.00 0.00 0.00
Food Breakfast Eat-in Side Prep1/2-1 Starch

Pineapple Bread
158 2.00 0.00 0.00 0.00 0.00 0.00
Food Breakfast Eat-in Side Prep1/2-1 Starch

Pumpkin Bread
187 2.50 0.00 0.00 0.00 0.00 0.00
Food Breakfast Eat-in Side Prep1/2-1 Starch

Drop Biscuits
165 2.00 0.00 0.00 0.00 0.00 0.50
Food Breakfast Eat-in Side Prep<1/2 Starch

Mushroom-Topped Fillets
122 0.00 0.00 0.00 3.50 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Meat Fish

Stuffed Fish Fillets
197 1.00 0.00 0.00 3.00 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Meat Fish

Zucchini Fish Bake
157 0.00 0.00 2.00 3.50 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep1/2-1 Meat Fish

Packaged Rolls
100 1.00 0.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Starch

Banana
80 0.00 1.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Fruit

Orange
80 0.00 1.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Fruit

Celery
20 0.00 0.00 0.500000 0.00 0.00 0.00
Food SingleFoodItem Eat-in Vegetable

Carrots
40 0.00 0.00 1.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Vegetable

Yogurt
140 0.00 0.00 0.00 0.00 1.00 0.00
Food SingleFoodItem Eat-in Milk

Nonfat Frozen Yogurt
120 1.00 0.00 0.00 0.00 1.00 0.00
Food SingleFoodItem Eat-in Milk

Butter
80 0.00 0.00 0.00 0.00 0.00 1.00
Food SingleFoodItem Eat-in Fat

Toast
100 1.00 0.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Starch

Skim Milk
80 0.00 0.00 0.00 0.00 1.00 0.00
Food SingleFoodItem Eat-in Milk

Hot Cocoa
120 0.00 0.00 0.00 0.00 1.00 0.00
Food SingleFoodItem Eat-in Milk

Chocolate Milk
80 0.00 0.00 0.00 0.00 1.00 0.00
Food SingleFoodItem Eat-in Milk

Snow Peas
40 0.00 0.00 1.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Vegetable

Sliced Tomatoes
40 0.00 0.00 1.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Vegetable

Beets
80 0.00 0.00 1.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Vegetable

Squash
120 0.00 0.00 1.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Vegetable

Blackberries
80 0.00 1.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Fruit

Mango
100 0.00 1.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Fruit

Cantaloupe
80 0.00 1.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Fruit

Mandarin Oranges
100 0.00 1.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Fruit

Cherries
80 0.00 1.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Fruit

Peach
100 0.00 1.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Fruit

Cheese
35 0.00 0.00 0.00 1.00 0.00 0.00
Food SingleFoodItem Eat-in Meat

Cottage Cheese
55 0.00 0.00 0.00 1.00 0.00 0.00
Food SingleFoodItem Eat-in Meat

Turkey (Sliced)
35 0.00 0.00 0.00 1.00 0.00 0.00
Food SingleFoodItem Eat-in Meat

Sliced Chicken
35 0.00 0.00 0.00 1.00 0.00 0.00
Food SingleFoodItem Eat-in Meat

Hard Boiled Egg
80 0.00 0.00 0.00 1.00 0.00 0.00
Food SingleFoodItem Eat-in Meat

Avocado
45 0.00 0.00 0.00 0.00 0.00 1.00
Food SingleFoodItem Eat-in Fat

Bacon
45 0.00 0.00 0.00 0.00 0.00 1.00
Food SingleFoodItem Eat-in Fat

Peanut Butter
45 0.00 0.00 0.00 0.00 0.00 1.00
Food SingleFoodItem Eat-in Fat

Pesto Sauce
45 0.00 0.00 0.00 0.00 0.00 1.00
Food SingleFoodItem Eat-in Fat

Beans
100 1.00 0.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Starch

Corn
100 1.00 0.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Starch

Bagel
100 1.00 0.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Starch

English Muffin
100 1.00 0.00 0.00 0.00 0.00 0.00
Food SingleFoodItem Eat-in Starch

Water
0 0.00 0.00 0.00 0.00 0.00 0.00
Food Drink Non-Dairy No-Alcohol Any-Time

Wine
150 1.00 0.00 0.00 0.00 0.00 0.00
Food Drink Non-Dairy Alcohol Dinner

Beer
150 1.00 0.00 0.00 0.00 0.00
Food Drink Non-Dairy Alcohol Dinner

Mixed Vegetables
70 0.00 0.00 1.00 0.00 0.00 0.50
Food Lunch/Dinner Take Side Prep<1/2 Vegetable

Vegetable Medley
80 0.00 0.00 1.00 0.00 0.00 0.00
Food Lunch/Dinner Take Side Prep<1/2 Vegetable

Mixed Salad
160 0.00 0.00 1.00 0.00 0.00 1.00
Food Lunch/Dinner Take Side Prep1/2-1 Vegetable

Hashbrowns
158 1.00 0.00 0.00 0.00 0.00 0.00
Food Breakfast Eat-in Side Prep1/2-1 Starch

Fresh Fruit Salad
140 0.00 1.00 0.00 0.00 0.00 0.00
Food Breakfast Eat-in Side Prep<1/2 Fruit

Eggs Benedict
200 0.00 0.00 0.00 2.00 0.00 1.00
Food Breakfast Eat-in Entree Prep<1/2 Eggs

Scrambled Eggs
120 0.00 0.00 0.00 2.00 0.00 1.00
Food Breakfast Eat-in Entree Prep<1/2 Eggs

Bacon
140 0.00 0.00 0.00 0.00 0.00 1.00
Food Breakfast Eat-in Side Prep<1/2 Meat

Ham
140 0.00 0.00 0.00 1.00 0.00 0.00
Food Breakfast Eat-in Side Prep<1/2 Meat

Steak
180 0.00 0.00 0.00 2.00 0.00 1.00
Food Breakfast Eat-in Entree Prep<1/2 Meat

Cornmeal Mush
120 1.00 0.00 0.00 0.00 0.00 1.00
Food Breakfast Eat-in Entree Prep<1/2 Cereals NULL 84

Oatmeal with Raisins
120 1.00 1.00 0.00 0.00 0.00 0.00
Food Breakfast Eat-in Entree Prep<1/2 Cereals

Orange/Banana Smoothie
120 0.00 2.00 0.00 0.00 1.00 0.00
Food Breakfast Eat-in Entree Prep<1/2 BreakfastDrinks

Strawberry Smoothie
120 0.00 2.00 0.00 0.00 1.00 0.00
Food Breakfast Eat-in Entree Prep<1/2 BreakfastDrinks

Clam Chowder
250 1.00 0.00 0.00 0.50 1.00 1.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Soup/Stew CreamBase

Potato Soup
225 1.00 0.00 0.00 0.00 1.00 1.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Soup/Stew CreamBase

Tomato Soup
175 0.00 0.00 1.00 0.00 1.00 0.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Soup/Stew TomatoBase

Minestrone
150 1.00 0.00 2.00 0.00 0.00 0.00
Food Lunch/Dinner Eat-in Entree Prep<1/2 Soup/Stew TomatoBase

White Rice
250 1.00 0.00 0.00 0.00 0.00 0.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Rice White

Brown Rice
250 1.00 0.00 0.00 0.00 0.00 0.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Rice Brown

Broccoli Rice
160 1.00 0.00 0.50 0.00 0.50 0.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Rice Other

Macaroni and Cheese
356 2.00 0.00 0.00 0.00 1.00 1.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Pasta Other

Pasta with Roasted Peppers and Basil
279 1.00 0.00 1.00 0.00 0.00 0.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Pasta Other

Fettuccine Alfredo
345 2.00 0.00 0.00 1.00 1.00 1.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Pasta White

Spaghetti
345 2.00 0.00 0.00 1.00 0.00 1.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Pasta Red

Layered Cranberry Applesauce Salad
120 0.00 1.00 0.00 0.00 0.00 0.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Fruit

Five Fruit Salad
81 0.00 1.00 0.00 0.00 0.00 0.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Fruit

Grapefruit Salad with Champagne Dressing
109 0.00 1.00 0.00 0.00 0.00 0.50
Food Lunch/Dinner Eat-in Side Prep<1/2 Fruit

Citrus, Fig, and Prosciutto Salad
174 0.00 1.00 0.00 0.00 0.00 1.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Fruit

Mediterranean Lentil Salad
254 0.00 0.00 0.00 1.50 0.00 1.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Salad

Sliced Tomato and Onion Salad
34 4 0.00 0.00 0.50 0.00 0.00 0.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Vegetable

Braised Leeks with Tomatoes
62 0.00 0.00 1.00 0.00 0.00 0.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Vegetable

Grilled Eggplant with Sesame Marinade
58 0.00 0.00 1.00 0.00 0.00 0.00
Food Lunch/Dinner Eat-in Side Prep<1/2 Vegetable

Potato Skins with Cheese and Bacon
106 1.00 0.00 0.00 0.00 0.00 1.00
Food Snack/Appetizers Eat-in Casual Prep<1/2 Starch

Chicken Salad-Filled Cream Puffs
47 1.00 0.00 0.00 0.50 0.00 0.50
Food Snack/Appetizers Eat-in Casual Prep<1/2 Starch

Fresh Fruit
47 0.00 1.00 0.00 0.00 0.00 0.00
Food Snack/Appetizers Eat-in Casual Prep<1/2 Fruit

Fruit Pizza
147 1.00 1.00 0.00 0.00 0.00 0.50
Food Snack/Appetizers Eat-in Casual Prep<1/2 Fruit

APPENDIX C

LIST OF NODES IN HIERARCHY

The following is a list of nodes in the hierarchy. Each node represents a meal component category. The left justified nodes are nodes in the first (root) and second level of the hierarchy. Each line under these nodes represent a new categorization level. The Nodes found on the same line are nodes at the same level in the hierarchy. If a line is found that has an already listed node followed by a ":", the following nodes found on the same line are children of that node.

Example:
Lunch
  Eat-in Take
  Entree
  Prep<1/2 Prep1/2-1 Prep>1
  Meatless Vegetarian Pasta Rice Casserole Meat

  Meat: Poultry Lamb Seafood Shellfish Beef Pork Fish WildGame Other
*Note: Take = Take-out

Lunch is in the second level of the hierarchy. Its children are Eat-in and Take. These have an Entrée child (other nodes at this level may be listed in another entry). Entrée has three children (Prep<1/2, Prep1/2-1, Prep>1). These each have six children (Meatless, Vegetarian, Pasta, Rice, Casserole, Meat). Meat has nine children listed in the last line of the example.

The following are all node types found in the hierarchy:

Food (root)
SingleFoodItem
  Eat-in Take
  Starch Fruit Vegetable Milk Meat Fat
Dessert
Drink
  Dairy Non-Dairy
  No-Alcohol Alcohol
  Lunch/Dinner Breakfast Lunch Dinner Snack Any-Time
  Snack/Appetizers
  Eat-in Take
  Formal Casual
  Prep<1/2 Prep1/2-1 Prep>1
  Starch Fruit Meat Milk Fat
Lunch
  Eat-in Take
  Entree
  Prep<1/2 Prep1/2-1 Prep>1
  Meatless Vegetarian Pasta Rice Casserole Meat

  Meat: Poultry Lamb Seafood Shellfish Beef Pork Fish WildGame Other Food

Lunch/Dinner
Eat-in Take
Entree
Prep<1/2 Prep1/2-1 Prep>1
Meatless Vegetarian Pasta Rice Casserole Meat

Meat: Poultry Lamb Seafood Shellfish Beef Pork Fish WildGame Other Food

Dinner
Eat-in Take
Entree
Prep<1/2 Prep1/2-1 Prep>1
Meatless Vegetarian Pasta Rice Casserole Meat Soup/Stew

Meat: Poultry Lamb Seafood Shellfish Beef Pork Fish WildGame Other Food
Soup/Stew: TomatoBase CreamBase Meatless Meat

Lunch
Eat-in Take
Side
Prep<1/2 Prep1/2-1 Prep>1
Vegetable Starch Rice Pasta Fruit Salad Rice Pasta

Rice: White Brown Other
Pasta: White Red Other

Lunch/Dinner
Eat-in Take
Side
Prep<1/2 Prep1/2-1 Prep>1
Vegetable Starch Rice Pasta Fruit Salad Rice Pasta

Rice: White Brown Other
Pasta: White Red Other

Breakfast
Eat-in Take

Entree
Prep<1/2 Prep1/2-1 Prep>1
Breakfast Drinks Eggs Meat Cereals Starch

Side
Prep<1/2 Prep1/2-1 Prep>1
Vegetable Fruit Starch Cereal Meat

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