A MENU PLANNING MODEL USING HYBRID GENETIC ALGORITHM AND FUZZY REASONING: A STUDY ON MALAYSIAN GERIATRIC CANCER PATIENTS

NGO HEA CHOON

UNIVERSITI SAINS MALAYSIA

2016

A MENU PLANNING MODEL USING HYBRID GENETIC ALGORITHM AND FUZZY REASONING: A STUDY ON MALAYSIAN GERIATRIC CANCER PATIENTS

by

NGO HEA CHOON

Thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

April 2016

ACKNOWLEDGEMENT

This research would not have been possible without the help of others who I would like to thank. First and foremost, I thank God for His blessings and guidance.

I would like to thank my supervisor, Associate Professor Dr. Cheah Yu-N for his excellent supervision, guidance and continuous encouragement during the research work and preparation of this thesis. I appreciate all his contributions of time and knowledge and many insightful discussions and suggestions. He has greatly helped me in a lot of ways throughout this study. Again, I owe my deepest gratitude to him.

I would like to extend my thanks to the Ministry of Education Malaysia and Universiti Teknikal Malaysia Melaka (UTeM) for providing all the facilities and the scholarship for this study. I am also grateful to the staff of the School of Computer Sciences, Universiti Sains Malaysia (USM), for their kind cooperation during my study.

In addition, I am grateful to the National Cancer Society Malaysia (Penang Branch), Nutrition & Dietetics Unit, Hospital Lam Wah Ee and Mount Miriam Cancer Hospital and individuals who show their cooperation and willingness to accept and entertain my presence even with their busy working schedule.

Last but not least, I sincerely thank and appreciate the love of my parents, my wife, my sisters and brothers for their prayers, time and thoughtful advice throughout my study.

TABLE OF CONTENTS

CHAPTER 3 - RESEARCH METHODOLOGY

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADA	American Dietetic Association
AHP	Analytical Hierarchy Process
ANN	Artificial Neural Network
BGL	Blood Glucose Level
BMI	Body Mass Index
CAMP	Case-Based Menu Planner
CAMPER	CAMP Enhanced by Rules
CBR	Case-Based Reasoning
CD	Caloric Density
DHL	Dietary Health Level
EA	Evolutionary Algorithm
FGB	Food Group Balance
fJSP	Flexible Job-shop Scheduling Problem
FLC	Fuzzy Logic Control
FML	Fuzzy Modelling Language
GOMS	Goal-Operator-Methods-Selection
HCA	Hierarchical Clustering Algorithm
HGA	Hybrid Genetic Algorithm
HL7	Health Level Seven International
IARC	International Agency for Research on Cancer
IS	Insertion Search
ISCR	Insertion Search with Cut-and-Repair

JSP	Job-shop Scheduling Problem
GA	Genetic Algorithm
GFML	Genetic Fuzzy Markup Language
LOINC	Logical Observation Identifiers Names and Codes
MCDA	Multi-Criteria Decision Analysis
MCDM	Multiple-Criteria Decision Making
MDKP	Multi-Dimensional Knapsack Problem
MOH	Ministry of Health Malaysia
MPCF	Machine-Part Cell Formation
MPP	Monitored Parameter Propositions
NCCFNM	National Coordinating Committee on Food and Nutriiton Malaysia
NCP	Nutrition Care Process
NSGA-II	Non-dominated Sorting Genetic Algorithm II
OPPs	Observed Parameter Propositions
PCC	Percentage of Calories from Carbohydrate
PCF	Percentage of Calories from Fat
PCP	Percentage of Calories from Protein
PCR	Percentage of Caloric Ratio
PRISM	Pattern Regulator for the Intelligent Selection of Menus
RBR	Rule-Based Reasoning
RNI	Recommended Nutrient Intake
SGA	Subjective Global Assessment
SMP	Self-adaptive Mutation Probability
SNOMED	Systematized Nomenclature of Medicine

CT	Clinical Terms
STRIPS	Standford Research Institute Problem Solver
T2FO	Type-2 Fuzzy Ontology
USDA	U.S. Department of Agriculture

MODEL PERANCANGAN MENU MENGGUNAKAN ALGORITMA GENETIK HIBRID DAN PENAAKULAN KABUR: KAJIAN TERHADAP PESAKIT KANSER GERIATRIK DI MALAYSIA

ABSTRAK

Dewasa ini, terdapat banyak model perancangan menu yang menyediakan nasihat umum kepada pelanggan di pasaran. Namun, penyelesaian yang dijana daripada model ini biasanya sangat subjektif dan sukar untuk diwakili secara sistematik. Oleh itu, pemakanan yang betul bagi warga tua adalah penting untuk mengekalkan kesihatan dan kesejahteraan. Kajian ini menghasilkan model perancangan menu berasaskan ontologi menggunakan algoritma genetik hibrid dan penaakulan kabur terhadap pesakit kanser geriatrik di Malaysia. Kajian ini adalah bertujuan untuk mengemukakan perwakilan pelan diet berdasarkan ontologi pelan diet; mereka bentuk enjin perancangan dengan mengintegrasikan algoritma genetik dengan pencarian setempat untuk memperbaiki pelan menu; membangunkan pelan menu untuk pesakit tersebut dengan menggunakan mekanisme penaakulan kabur. Dengan tujuan untuk merancang menu yang sihat kepada pesakit, ontologi digunakan untuk mengklasifikasikan nutrien, jenis makanan, struktur pemakanan dan profil peribadi. Selain itu, algoritma genetik hibrid (HGA) digunakan untuk memastikan bahawa perancangan menu dapat memenuhi semua objektif dan kekangan yang telah ditetapkan. Tambahan pula, kawalan logik kabur (FLC) diaplikasikan dalam pemodelan fungsi keahlian set kabur bagi menganggarkan keperluan pemakanan. Keputusan yang diperolehi melalui kajian ini menunjukkan

bahawa pendekatan HGA dapat menghasilkan penyelesaian yang boleh diterima dan FLC dapat menghasilkan peningkatan yang ketara dalam model perancangan menu yang dicadangkan.

A MENU PLANNING MODEL USING HYBRID GENETIC ALGORITHM AND FUZZY REASONING: A STUDY ON MALAYSIAN GERIATRIC CANCER PATIENTS

ABSTRACT

Nowadays, there are many diet recommendation models in the market that provide general advice to the clients. However, the generated menu plan from these models are usually very subjective and difficult to be represented systematically. Thus, proper nutrition for the elderly is important to maintain health and well-being, which can lead to fulfilling and independent lives. This research presents a study on ontology-based menu planning model using hybrid genetic algorithm and fuzzy reasoning for Malaysian geriatric cancer patients. The proposed work aims to produce a diet plan representation based on diet plan ontology; design a planning engine by integrating genetic algorithm with local search technique to enhance menu planning; and develop a menu planning approach to cater for Malaysian geriatric cancer patients using fuzzy reasoning mechanism. With the aim of planning healthy menu to patients, ontology is used to classify nutrients, food groups, meal structure and personal profile. Following that, hybrid genetic algorithm (HGA) is employed to ensure that the constructed menu satisfies all the objectives and predefined constraints. Furthermore, a fuzzy logic control (FLC) was applied in the modeling of membership functions of fuzzy sets for estimating nutrition needs. The evidence from this study showed that HGA approach was capable

to produce feasible solutions and FLC yielded significant improvements in the proposed menu planning model.

CHAPTER 1

INTRODUCTION

1.1 Background

Planning is considered as a search-based problem solving in coming up with a series of actions which will achieve a goal (Allen et al., 1990). Planning is also widely used in many areas such as in medicine, administration, business, logistics, education, environment and family matters. In automated-planning research, the word "plans" refers specifically to plans of action. It is about the representation of future behavior, generally a series of actions, with temporal and other constraints on them for execution by some agents. Theoretically, planning is an important part of rational behavior. Therefore, planning plays a critical role in modeling the computational aspects of intelligence (Nau, 2007; Ghallab et al., 2004).

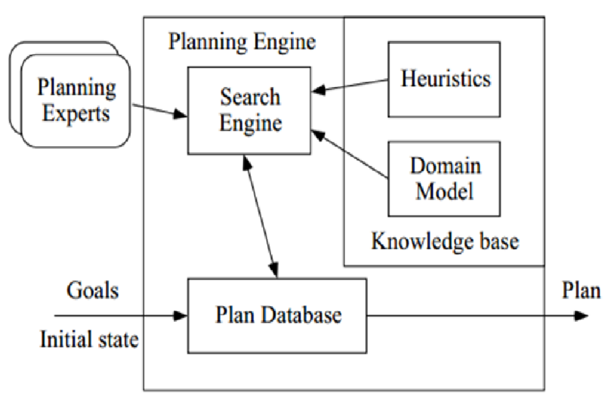

Figure 1.1: The Architecture of the Planning Model (Jónsson et al, 2000)

The architecture of the planning model is shown in Figure 1.1. The domain model describes the dynamics of the system in which the planner is being used. A plan request contains an initial state and a set of goals, initializes the plan database. The search engine retrieve data from the plan database to create a comprehensive plan, which is sent to the execution agent. The heuristics provide guidance for the search engine and the planning experts provide an interface to external systems, whose inputs the planner has to take into account (Jónsson et al, 2000).

1.1.1 Menu Planning

Menu planning, a more domain specific type of planning is considered as a complex task that some researchers have attempted to computerize since the early 1960s (Balitfy, 1964; Eckstein, 1967). Menu planning problem is to find an optimal combination of menu items that meets particular nutritional, structural, and variety requirements for a sequence of days (Balintfy, 1964). Besides, menu planning also involves the simultaneous consideration of several kinds of constraints such as the desired nutritional content, the preferences of the person, the number of meal, and the expected form and the variety of meals (Kovacic, 1995). Studies in the area of automated menu planning often find different ways to generate meals to meet the needs of users and constraints.

The survey done in government hospitals reveals that the nutritionist from the Ministry of Health is responsible for planning menus for patients for a period of six months. The suggested menu plan is delivered to all the hospitals around Malaysia. According to the interview session with the dieticians at the Nutrition & Dietetics Unit at Hospital Lam Wah Ee and Mount Miriam Cancer Hospital, the current practice in menu planning is a manual calculation method using an Excel spreadsheet. They use trial and error approach in swapping the menu items to meet the nutrition guidelines and the needs of individual users. In the hospital, nutritionists or dieticians consider only four kinds of macronutrients which are energy, carbohydrates, protein and fat, as the inclusion of other micronutrients may result in difficulty and complexity in getting the best solution.

Table 1.1: An Example of a Menu

Meal	Choices	Menu
Breakfast	A	White bread /whole meal bread (spread with butter /jam /kaya /peanut) Hard-boiled Egg /Half-boiled Egg /Scrambled Egg /Omelette /Fried Egg /Cheese
	B	Dosai+Dalca (with tomato and carrot)
	C	Oat+Raisin (with /without Sugar and Milk)
	D	Vegetarian Porridge (with pumpkin, red bean, tofu, peanut, mushroom, carrot, sweet corn)
	E	Noodle /Bee Hoon /Koay Teow /Mee Suah Chicken Soup
Drinks	-	Milk/ Milo/ Horlicks/ Coffee/ Tea
Morning Tea	-	Kuih Bahulu/ Swiss roll/ Cake Barley Water/ Chrysanthemum Tea/ Honey Water
Lunch	A	White Rice/ Brown Rice/ Plain Porridge Steamed Tenggiri Fish, Teow Chew-style Steamed Cabbage Roll (stuffed with spinach, carrot, and French beans)
	B	White Rice/ Brown Rice/ Plain Porridge Steamed Chicken with oyster sauce Steamed cabbage roll (with spinach, carrot, and French beans)
	C	Chinese Fried Rice (with Fish/ Chicken)
	D	Fish Porridge/ Chicken Porridge/ Vegetable Porridge (with pumpkin, red bean, tofu, peanut, mushroom, carrot, sweet corn)
	E	Noodle /Bee Hoon /Koay Teow /Mee Suah Nutritious Soup (Chicken+Potato+Pumpkin+Corn+Carrot+Tomato)
Dessert	-	Papaya/ Fruit juice/ Pudding with cubed fruit inside
Afternoon Tea	-	Popia Basah/ Apam kukus/ Pandan cake/ Red bean soup (with sugar)
Dinner	A	White Rice/ Brown Rice/ Plain Porridge Fried Fish with sweet and sour sauce topping Stir-fried Bitter Gourd with Egg
	B	White Rice/ Brown Rice/ Plain Porridge Fried Chicken with lemon sauce topping
	C	Fried Bee Hoon (with Fish/ Chicken)
	D	Fish Porridge/ Chicken Porridge/ Vegetable Porridge (with pumpkin, red bean, tofu, peanut, mushroom, carrot, sweet corn)
	E	Noodle /Bee Hoon /Koay Teow /Mee Suah Nutritious Soup (Chicken+Potato+Pumpkin+Corn+Carrot+Tomato)
Dessert	-	Dragon fruit/ Fruit juice/ Pudding with cubed fruit inside
Supper		Cream crackers/ Marie biscuits Milo + Milk

Table 1.1 shows an example of a menu. In the hospital, caterers are employed to prepare food for the patients and they are responsible to provide six meals a day consisting of breakfast, morning snack, lunch, afternoon snack, dinner and supper. The Malaysian Government is committed to allocate a certain budget to the patients for their daily meals. Caterers are responsible to provide suitable menus for the patients. For those working in the administrative divisions, they are responsible in ensuring that the meals provided by the caterer is according to the plan. However, caterers are given the option to choose the appropriate menus based on their cooking expertise, availability of ingredients, capability of human resources, food costs and total budget. The goal of the government and the hospital is to use the entire budget to provide nutritious meals as suggested by food pyramid that can fulfill the standard Recommended Nutrient Intake (RNI) requirements to ensure the patients always get a balanced and nutritious diet. On the other hand, profit maximization is usually the main objective of any business entity. As such, the caterer who is responsible for providing the menus would aim to minimize the total cost. In doing so, there is a possibility that the cost factor will prevail over nutrients.

In some other cases, the elderly are provided with menus that are limited in terms of variety. As such, appropriate menu planning to meet the three stakeholders (the patients, the caterers and the hospitals) can be very complicated and deserve special attention. Therefore, to solve the problems faced by the stakeholders, a new menu planning model has to be designed and developed that will be able to meet objectives and overcome some constraints using optimization and meta-heuristic approaches to produce better solutions. Instead of using manual calculations, the menu planning model could offer a more effective way to plan daily meals and it can help the hospital in generating a healthy daily meals for the patients.

1.1.2 Malnutrition among Geriatric Cancer Patients

The elderly population is growing rapidly worldwide, because of rising life expectancy and declining birth rates, leading to fewer young people, due to medical care based on the use of drugs and several advances in medical care. According to World Health Organization (WHO), there are an estimated 605 million elderly people (60 years old and above) in the world today. By 2025, it is estimated that the proportion of the population aged 60 and older will reach 11% in South and Central Asia (WHO, 2002). The proportion of the population aged 65 and older also increased to 5.3% from 3.9% in 2000 in Malaysia (Department of Statistics Malaysia, 2013). Figure 1.2 shows the total population of people aged 60 and older (UNFPA, 2013).

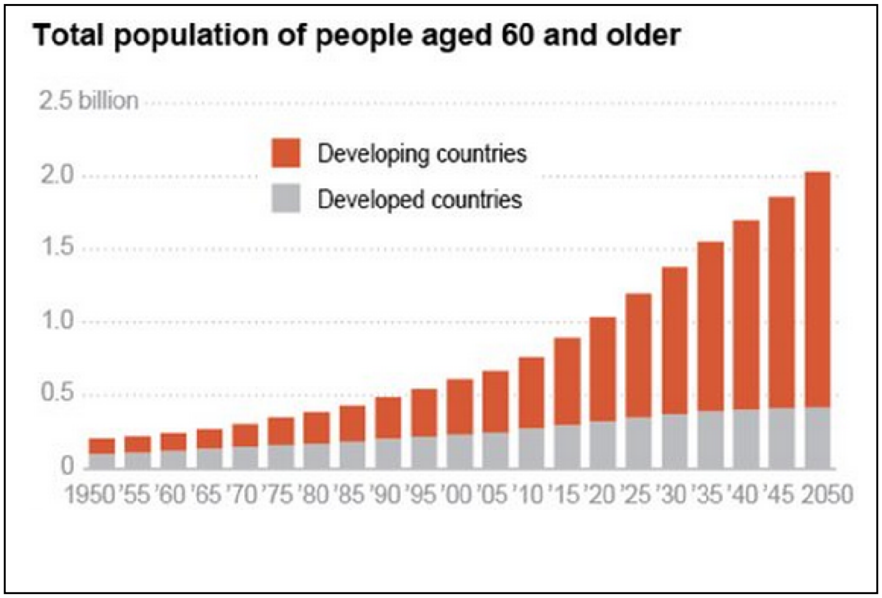

Figure 1.2: Total Population of People Aged 60 and Older (UNFPA, 2013)

Many people stay healthy as they get older, but they experience changes in body composition and organ systems metabolism (Harrison and Waterloo, 1990; Prentice, 1992). These changes occur in different people at very different rates. In some seniors, the immune system begins to operate less well. Several studies have shown that the elderly are at high risk of malnutrition (Jensen et al., 2001; Suzana et al., 2002). Malnutrition includes both overnutrtion and undernutrition. In Malaysia, the main reason for concern among geriatrics in hospitals is that they do not eat enough to maintain good diet. Malnutrition can contribute to some health problems. Therefore, good diet plays a crucial role in caring for the elderly.

The Tenth Malaysia Health Plan (2011-2015) has mentioned that one of the biggest challenges will be how to postpone and prevent disability and disease and to maintain the health, independence and mobility for an ageing population. Many of the biological changes and risks for chronic disease that have been traditionally attributed to ageing are actually caused by malnutrition (Chandra et al., 1982; Potter et al., 1995; Vellas et al., 1997). Therefore, physical activity and a good nutrition are essential to help reduce potential health problems such as diabetes mellitus, muscle and bone disorders, constipation and other digestive disorders, anemia, overweight, stroke and coronary heart disease. Besides, nutrition also plays a crucial role to achieve a good recovery from surgery and illnesses (Caroline Walker Trust, 1995).

In this thesis, a menu planning model for Malaysian geriatric cancer patients was studied. According to the latest Health Facts 2013 released by the Ministry of Health (MOH) Malaysia, cancer is one of the top ten major causes of hospitalization and one of the top five causes of death in both private and government hospitals. Mortality due to cancer deaths totaled 20,100 in 2008 and has grown to 21,700 deaths in 2012, based on the International Agency for Research on Cancer (IARC) Globocan of the World Health Organization. Malnutrition is likely to develop or worsen during specific cancer treatments (radiotherapy, systemic therapy, surgery) especially when early and adequate nutritional intervention is not well indicated (Andreyev et al., 1998; Ross et al., 2004). Depending on tumor location, treatment and stage, the prevalence of malnutrition in cancer patients ranges from 8-84% (Maarten von Meyenfeldt, 2005; Brown et al., 1991). Therefore, early nutrition intervention is important to prevent or reverse the onset of malnutrition and to improve the prognosis of cancer patients in the recovery cycle.

1.1.3 Menu Planning Methods

Menu planning can be categorized as NP-hard problem (Seljak, 2009). It involves thousands of variable menu items and hundreds of constraints which are suited for optimization approaches. In addition, it is costly and difficult to find the optimal set of menu items from a large solution space. Finding the optimal solution is not the main concern for planning the menu as long as the solution satisfies all the constraints that meet the needs of the RNI and within budget. Rather than using optimization approaches, some researchers used meta-heuristic approaches such as genetic algorithm (GA) to solve the problem of planning the menu (Kahraman and

Seven, 2005; Seljak, 2009). Although GA is able to produce feasible solutions, but it cannot guarantee a feasible solution in all cases because many constraints have to be considered (El-Mihoub et al., 2006). Thus, the genetic algorithm hybridization with other methods is expected to assist the search towards a feasible solution.

The drawback of existing hybrid genetic algorithm approaches developed by Kahraman and Seven (2005), Kaldirim and Köse (2006) and Seljak (2009) is that the infeasible individual is allowed to enter the next generation after crossover and mutation operations. Only local search is applied in the initialization step which may lead to loss of good solutions. Therefore, more restrictions should be made to ensure only feasible solutions are considered for the new generation to reduce the number of infeasible solutions in the population. This study aims to fill the gap to improve the performance of previous hybrid genetic algorithm approaches.

To date, various methods have been proposed and used to solve the menu planning problem. Currently, the combination of optimization and meta-heuristic approaches has become a popular approach in solving the menu planning problem. For instance, trial and error exchange menu items (Noah et al., 2004), steady-state genetic algorithms (Kahraman and Seven, 2005), multi-objective genetic algorithms with NSGA-II (Kaldirim and Kőse, 2006) and evolutionary algorithm (Seljak, 2009). Further details on these methods and other related methods will be discussed in Chapter 2.

Ontology was defined by Gruber (1993) as an "explicit specification of a conceptualization". An ontology specifies the name and the description of the domain-specific entities using predicates that represent the relationships between these entities. The ontology provides a vocabulary to communicate and represent knowledge along with a number of relationships containing the vocabulary terms conceptually. In addition, ontology is a good model of communication and knowledge representation for intelligent agents (Lee et al., 2005). Consequently, the use of ontologies to provide interoperability between heterogeneous data sources has been adapted in many fields, such as medical information systems (Orgun and Vu, 2005).

Ontology has become a powerful way to share and express the knowledge of the community and its semantics (Reformat and Ly, 2009), to provide description of common vocabularies, and to guide intelligent querying from different database (Stevens et al., 2001; Baker et al., 1999). The sharing is often a matter of creating a community of users, and building a support for a standard, such as the HL7, DICOM, SNOMED CT and LOINC (Taylor, 2006). There are some studies used the ontology to healthcare, such as the electrocardiogram application (Lee et al., 2008) and respiratory waveform recognition (Lee and Wang, 2007).

The benefits of fuzzy reasoning in dealing with this problem was investigated. Here, fuzzy reasoning is proposed to improve the generated menu plan. Fuzzy reasoning is a natural approach for knowledge representation based on degrees of membership. One of the advantages of fuzzy reasoning systems is to describe fuzzy rules that match the description of the real-world processes to a greater extent (Valishevsky, 2002). Another advantages lies in the interpretability; it means that it is possible to explain why a specific value appeared at the output of the fuzzy system.

Instead of Boolean logic, fuzzy logic uses a collection of fuzzy variables defined by the membership functions and inference rules (Gedrich et al., 1999; Gajdoš et al., 2001; Rumora et al., 2009). Fuzzy membership functions are constructed to describe the range of nutrient intake in the range from inadequate to excess amounts. A nutritionist important task is to improve the eating habits of the elderly population that will help to reduce the incidence of cancer and morbidity of many other chronic diseases like diabetes. Therefore, the medical nutrition therapy for cancer is important to guide dietician towards a standardized dietary management along the process of nutrition education for patients with cancer in order to improve patient outcome (ADA, 2007).

The evaluation of menu plans has at least two sides. At first, it should consider the amount of nutrients in the menu plan. Regarding quantity, the work of menu planning can be formulated as a constraint satisfaction and optimization problems. Secondly, it should consider the meal structure of menu plan. Plans satisfying the constraints of diet should also be appetizing. The meal dishes should go together. With common sense some dishes or nutrients are not addressed in the way others do.

Ultimately, to test the efficiency and effectiveness of any proposed menu planning method, evaluation on the model needs to be carried out to determine the accuracy of the planned menu. The dietician-prepared plans were used as the benchmark to evaluate the performance of the proposed menu planning model compared to human planning. In this study, some reviews of current techniques used in planning menu among Malaysian nutritionists and dieticians were held through a survey and interview session in order to gain more information which can benefit this study.

1.2 Research Questions

By understanding the background which has been discussed in the previous section, it can be concluded that issues in the field of automated menu planning studies still need more investigation. Besides coming up with new ideas for improvement, the limitations and gaps left by past research works pose some key questions to be answered in this thesis. Here, the following research questions are put forward that will be further investigated in this study.

1. How can genetic algorithm produce the generated menu plan with a feasible solution?

2. How can local search technique and fuzzy reasoning approach be employed in the menu planning problem to further improve the quality of the solution generated by the genetic algorithm?

1.3 Research Objectives

The main goal of this research is not only to design and develop efficient ontology-based and hybrid genetic algorithm for menu planning problems but also to show that these approaches can outperform others. Thus, to achieve the abovementioned aim, the following objectives have been set.

1. To define the use of genetic algorithm that can meet the significant constraints (nutrition, cost and variety) of the proposed model.

2. To hybridise the use of genetic algorithm with local search and fuzzy reasoning approach in order to further improve the quality of the solution generated by the genetic algorithm.

1.4 Scope of the Study

As stated earlier, this research was designed to produce a menu planning model for geriatric cancer patients for the purpose of generating a menu plan using the proposed techniques. In this study, a global optimization technique, genetic algorithm (GA) is used as the mainstream approach for the menu planning model since it is robust and offers significant benefits over typical optimization techniques such as linear programming. Furthermore, GA is hybridised with local search and fuzzy reasoning to improve the quality of the solution. The proposed method was applied to the geriatric cancer patients with the support of the dieticians of Hospital Lam Wah Ee and Mount Miriam Cancer Hospital. The patients of these hospitals comprise of people from the various states across Malaysia.

The data of menu items and its nutrition value are obtained from the Malaysian Food Composition Tables (Tee et al., 2002) and Atlas of Food Exchanges and Portion Sizes (Suzana et al, 2009). The meals were grouped into breakfast, morning snack, lunch, afternoon snack, dinner and supper. Eleven nutrients were considered including energy, fats, carbohydrate, protein, vitamin B_1, vitamin B_2, niacin, vitamin C, vitamin A, calcium and iron. Each of these nutrients is considered based on the lower bound and upper bound requirements respectively, with respect to the requirement of the elderly according to the Malaysian Dietary Guidelines (2010) and Guideline of Recommended Nutrient Intakes Malaysia (NCCFNM, 2005). Nutrition intervention towards cancer patient is obtained from Medical Nutrition Therapy Guidelines for Cancer in Adults (2013) and the American Cancer Society (2010).

1.5 Significance of the Study

There are several advantages of this study in the model of menu planning for Malaysian geriatric cancer patients. Firstly, this study addresses a new foundation for solving menu planning problem by using ontology-based and hybrid genetic algorithm approach. This proposed approach is able to consider a variety of menu items and satisfy the constraints related to cost, standard nutrition requirement and a variety of dishes. In addition, this study is adapted for children, adults, athletes and pregnant women by doing some adjustments in the data.

The role of ontology in this study is to facilitate the classification or organization of nutrients, foods, meals and personal profile. For this, the creation of a comprehensive ontology-based dietary knowledge base which consists of nutrients, foods and meals, defining the semantics of nutritional facts is proposed. Once nutrient/food/meal ontologies have been sufficiently created and integrated with each other, they will then play a role in planning healthy diets for geriatric cancer patients.

Finally, this study enhances the application of hybrid genetic algorithm theory with local search to solve real-world problems in menu planning. Moreover, the menu planning model is able to suggest meals for slight changes to diet for geriatric cancer patients using fuzzy reasoning. A fuzzy logic control system was applied in modeling of membership functions of fuzzy sets for estimating nutrition needs in geriatric cancer patients. This developed model may hopefully benefit human life using knowledge of meta-heuristics and optimization.

1.6 Thesis Organization

This section describes the organization of the thesis. There are altogether seven chapters in this thesis, which includes: Chapter 1 gives a general introduction on the topic of the proposed research work. Brief overviews of some of the issues concerning the research are also mentioned in this chapter. Besides the background, this chapters also included the research questions, research objectives, scope of the study and significance of the study. Chapter 2 provides the literature review in automated planning including plan representation and plan ontology, a conceptual model of planning, planning engine and the planning process, application of hybrid genetic algorithm and other related works. Chapter 3 provides an overview of the methodology used to achieve the research objectives of this study, which also includes the procedures that were conducted. Chapter 4 demonstrates the menu planning model development and Chapter 5 describes the extended menu planning model. Chapter 6 outlines description on the implementation of the proposed method, experiment, analysis and result of the proposed model. Finally, Chapter 7 concludes the main contributions of the proposed work and presents the future directions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Planning is the task of finding a sequence of events to accomplish a desired goal and meet a set of domain constraints. Planning research has focused mainly on finding a feasible set of actions that achieve one or more goals (Fox, 1994). The work of planning can be dated back to the 1960s. Since then, the field of planning has witnessed continuous involvement by many researchers in the attempt to look for different strategies to automate planning.

Classical planning mostly concentrates on robotic applications such as Blocks World Planning and STRIPS. The classical approach to the planning problem is to start from specifications of the states, actions and effects of the actions, and then try to infer a sequence of actions that achieves a particular state of affairs. However, current trends show that automated planning technology has become mature to be useful in applications ranging from space exploration to automated manufacturing (Nau, 2007).

2.2 Terminology Used in Menu Planning

Before discussing further on planning models and menu planning, the following are some basic terminologies in the context of this research.

2.2.1 Healthy Diet

A healthy diet is a diet that provides the right combination of energy and nutrients. Four characteristics explain a healthy diet: adequate, balanced, moderate and varied (NCCFNM, 2010).

2.2.2 Recommended Nutrient Intake (RNI)

The recommended nutrient intake is the dietary intake which satisfies the nutrient requirements of almost all (97-98%) healthy individuals. The range of intakes covered by the RNI and the tolerable upper limit of nutrient intake should be considered sufficient to prevent deficiency while avoiding toxicity (NCCFNM, 2005).

2.2.3 Food Guide Pyramid

The food guide pyramid was developed by the U.S. Department of Agriculture (USDA) to assist Americans follow the Dietary Guidelines for Americans (Drummond and Brefere, 2003). It is developed to provide a framework for the right amounts and types of foods that can be consumed in combination to meet nutritional needs. Figure 2.1 shows the food guide pyramid (NCCFNM, 2005).

Figure 2.1: Food Guide Pyramid (NCCFNM, 2005)

The food guide pyramid consists of four levels that represent various food groups. People are encouraged to eat less of foods at the top of the pyramid and more of foods at the base of the pyramid. A well-balanced diet and eating a variety of foods contribute towards the provision of a range of different nutrients to the body.

2.3 Planning Models

Automated planning models can be categorized into three main groups which are domain-specific planners, domain-configurable planners and domain-independent planners (Nau, 2007).

- ***Domain-specific planners*** are planning models that custom-built specifically in a particular domain. Normally, major modifications are implemented to the planning model for it to be functioned with other domains.

- ***Domain-configurable planners*** are domain-independent for planning engine but the input to the planners involves domain-specific knowledge to restrict the planner's search.

- ***Domain-independent planning models***, the sole input to the planner is a definition of a planning problem to deal with, and planning engine is able to function in any planning domain.

The proposed menu planning model in this study is a domain-configurable planner based on the characteristics of a menu planning problem which is considered more beneficial compared to domain-specific planner and domain-independent planner because: (i) it needs to address a description of domain only instead of an entire planner, (ii) it will have an average level of performance in a particular domain, (iii) it has greater coverage across various domains due to its efficiency and expressive power, (iv) it is able to deal with most of the problems in the fastest way and arrive at better solutions. In addition, it operates in many non-classical planning.

2.4 Planning Model Based on Ontologies and Generic Planning

A popular approach for plan representation is through ontologies and plans are designed based on project specific ontologies and the description of the domain languages.

2.4.1 PLANET

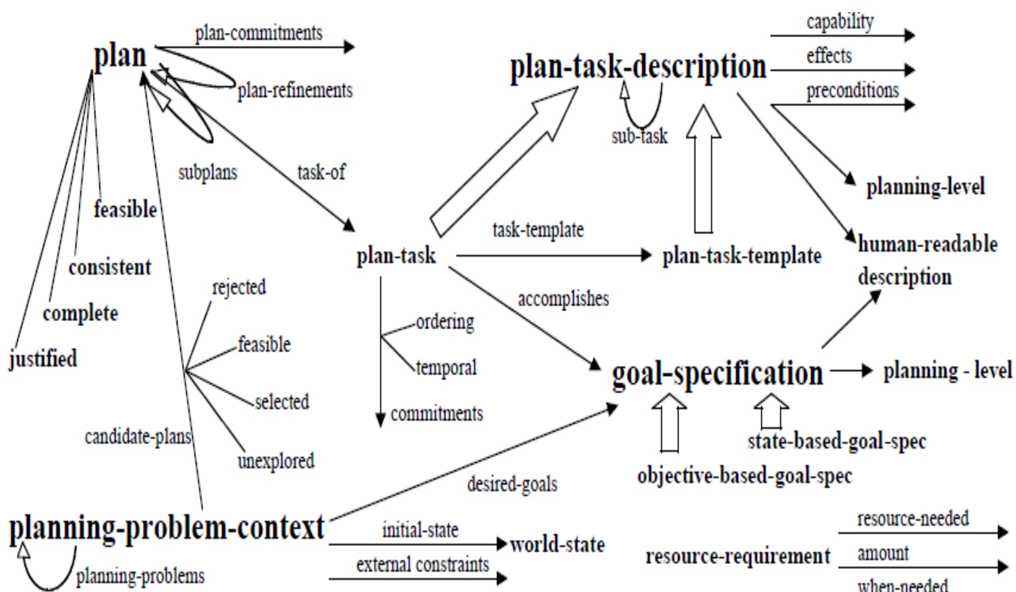

Figure 2.2: PLANET Ontology (Gil et al., 2000)

The PLANET is an ontology to represent plans. The PLANET is useful in knowledge modelling with a structure that formalizes important distinctions in the areas of planning, and to facilitate the integration of planning tools from the exchange of knowledge, and can be reused throughout the application of knowledge-based planning (Gil et al., 2000). Figure 2.2 shows an overview of the PLANET ontology.

2.4.2 O-Plan

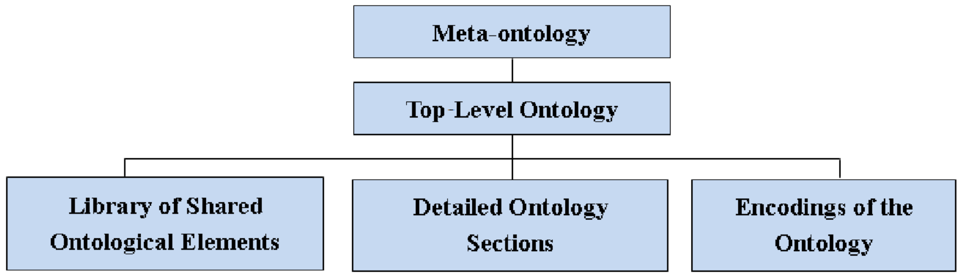

Figure 2.3: Plan Ontology Structure (Tate, 1997)

O-Plan is a domain-independent planner based on past experience with the Nonlin planner and its derivatives (Tate, 2003). This is an implementation and design of a more flexible system in terms of its contribution to research and development of planning. The structure of the O-Plan plan ontology is shown in Figure 2.3 and Figure 2.4 illustrates the framework of components in O-Plan.

- ***Meta-ontology*** describes the assumptions behind the description and the ontology itself.

- ***Top-Level Ontology*** includes surface level of the ontology or the basic ontology.

- ***Detailed Ontology Sections*** include the detailed ontological elements.

- ***Library of Shared Ontological Elements*** includes a group of ontological elements that can be shared between the detailed parts of the ontology.

- ***Encoding of the Ontology*** are statements that define the relationship between ontological attributes using symbols.

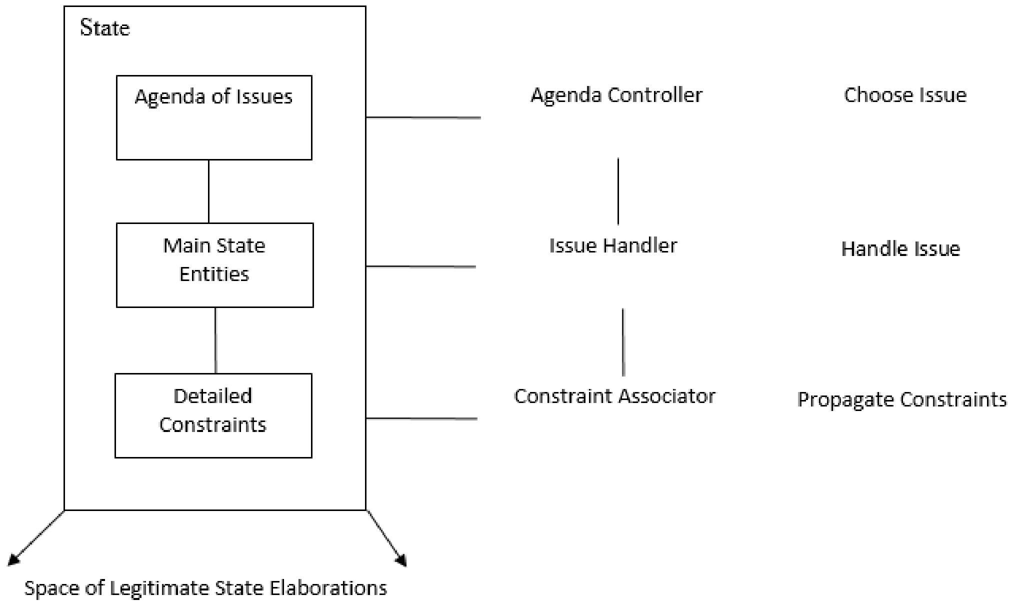

Figure 2.4: Components in a Planning System Framework (Tate, 1996)

O-Plan refines the "current state". It maintains one or more options within the state in which the previous alternative decisions about how to limit the field of state elaborations. The system needs to know what requirements are higher processing exist in the state. This represents the implicit constraints on future valid membership. One of the selected processing conditions is selected to be processed next by the *Agenda* or *Option Controller* (Tate, 1996).

It is useful to divide the entities that represent the decisions taken during processing at a high level represents the *Main State Entities* are shared by all components of the system and is known in various parts of the system, and more *Detailed Constraints* form the representation of the situation. This separation can support the recognition of modularity within the system (Tate, 1996).

The different components plug-in "sockets" in the architecture frameworks. The sockets are defined to facilitate the insertion of certain types of component (Tate, 1996). Figure 2.5 shows the architecture of O-Plan Agent. The various components of the agent architecture are described in Table 2.1.

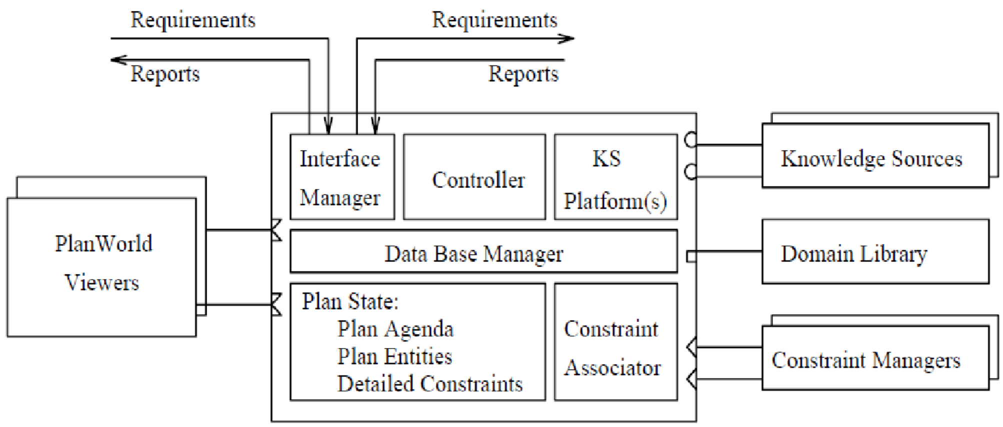

Figure 2.5: O-Plan Agent Architecture (Tate, 1996)

Table 2.1: Components of the Agent Architecture

Components	Description
Knowledge Sources	To modify plans or to analyse their synthesis. They provide the potential of the medium.
Plan World Viewers	Visualization, presentation viewers, and user interface for the plan. It is always differentiated in technical *plan views* and *world views.*
Domain Library	A domain explanation includes a library of all possible actions.
Constraint Manager	To manage detailed restrictions on the plan and look for maintaining as accurate a picture as possible of the feasibility of the current plan.

These plug-in components are coordinated by O-Plan agent kernel which performs the tasks assigned to the appropriate use of Knowledge Sources and makes choices retained in the agent's *Plan State*. The central control flow is as follows:

- ***Interface Manager*** conducts external events. They will then be posted to the agent *Agenda* if the agent can process them.

- ***Controller*** selects Agenda records for processing by appropriate Knowledge Sources.

- ***Knowledge Source Platform(s)*** selects Knowledge Sources behave in an appropriate and available Knowledge Source Platform.

- ***Data Base Manager*** provides services for the Interface, Manager Controller and Knowledge Sources and maintains the Plan State.

- ***Constraint Associator*** behaves as a mediator between the activities of the various Constraint Managers and changes to the state plan. It facilitates the management of interrelationships between the main plan entities and detailed constraints.

2.4.3 Asgaard

In the Asgaard project, a sequence of actions that support the implementation and the design of the skeletal plan by a human performance agent other than the original plan designer (Miksch et al., 1997). Asbru is a modeling language which emphasises on an expressive representation of the world situations and time-oriented actions. A proper plan is initialized with state-transition criteria. Distinctive arguments are combined to reason and execute about various tasks during the execution phase. In Asbru, a plan consists of name and a set of arguments. These arguments includes a time annotation and five major knowledge roles (Miksch et al., 1997):

- ***Plan layout*** describes the frequency of execution of sub-plan and order.

- ***Preferences*** place constraints on its applicability and describes the behaviour of the plan.

- ***Intentions*** are high-level goals at different levels of the plan that supports work on the re-planning and critiquing.

- ***Effects*** state the relationship between measurable and plan arguments.

- ***Conditions*** are temporal standards, modelled at a fixed frequency that need to keep to specific plan steps to induce a certain state transitions of the plan instance.

All plans and actions have a temporal dimension and plan execution is monitored by a number of conditions (Miksch and Seyfang, 2000). Figure 2.6 shows an overview of the communication model for Asgaard project. To support time-oriented planning in medicine, Asgaard emphasis on solving problem of task-specific methods (Hammermuller and Miksch, 1999). But, some of them are mostly completed at the time of design and others completed during runtime of skeletal plans (Miksch, 1999). Most of the tasks for the Asgaard project are shown in Table 2.2 and Table 2.3.

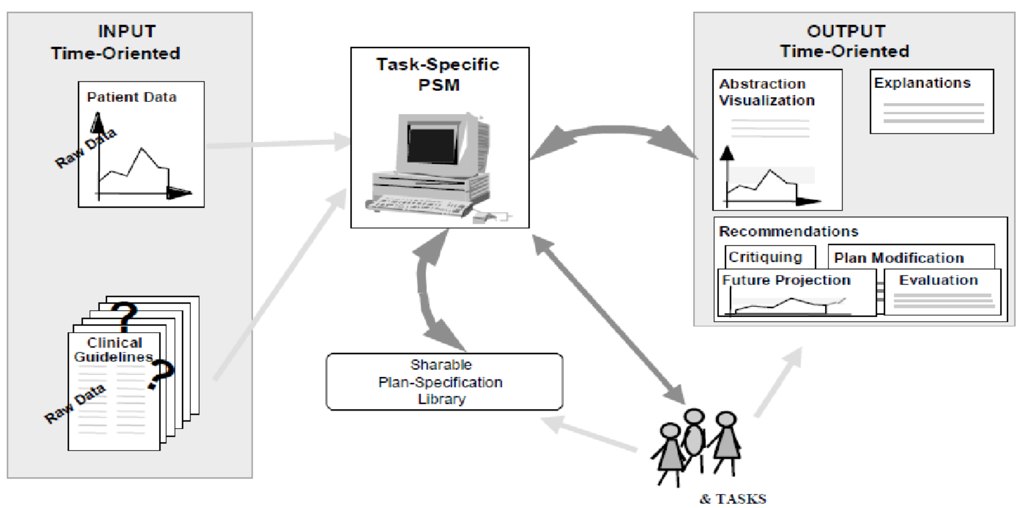

Figure 2.6: Overview of the Communication Model of the Asgaard Project (Hammermuller and Miksch, 1999)

Table 2.2: Tasks Mostly Done during Asgaard's Design Phase

Tasks	Description
Plan Visualization	A method to design and explore the topological and the temporal aspects of the interconnected plans graphically.
Advanced Plan Editing	A method to give full access to expert users by an editor guided by the knowledge roles.
Plan Verification	Investigate the truth of inter-related clinical plans through a three-level detection of anomalies.
Plan Validation	Match up the intended state at the prescribed actions and intended plans.
Plan-Scenario Testing	Check course of their activities and functions by using scenarios of plans.

Table 2.3: Tasks Mostly Done during Asgaard's Execution Phase

Tasks	Description
Plan Selection	Select the clinical plans of the plan library based on the effects of the plan, the patient's condition, and the general objectives of the plan.
Plan Instantiation	Change the parameters of the clinical plan based on the patient data record and medical environment.
Data Abstraction	Convert data into a format that is suitable for the monitoring unit from the sensors or user input.
Plan Monitoring	Understand applicability of the executed plans during the particular time of execution.
Plan Execution	Map plans and the actual situation in the medical environment that is done in three distinct layers: the plan adaptation, plan synchronization, and re-planning.
Plan Critiquing	Formed by critique of the performing agent's action and intention recognition.
Plan Evaluation	Evaluate retrospectively, if the generated plans achieved the desired result based on the patient's condition, intentions, plan effects, and executed actions.
Execution Visualization	Visualize which plans have been generated.
Plan Rationale/ History	Cataloguing states, events, performed actions and intentions; produces explanations and plan selection, states of execution, instantiation, success and failure of the plans integration of the domain-specific annotation.

Figure 2.7 shows the runtime modules of Asgaard that includes data abstraction unit, monitoring unit, and the execution unit (Miksch et al., 2001).

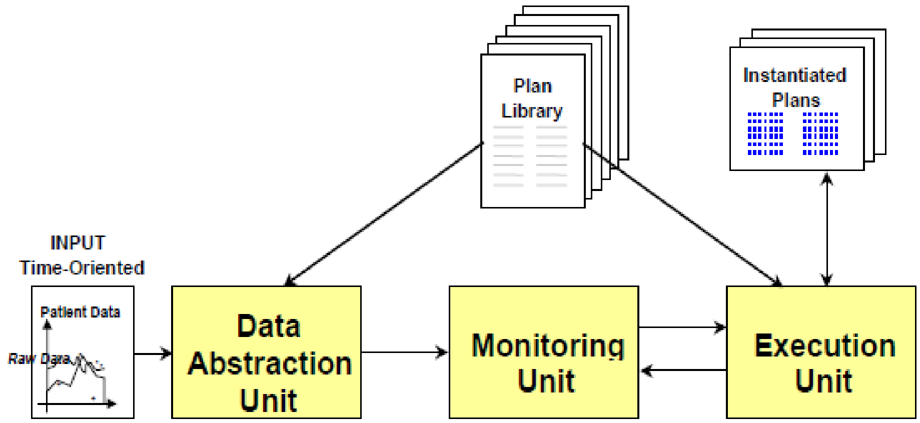

Figure 2.7: Runtime Modules of Asgaard (Miksch et al., 2001)

The data abstraction unit transform information into a form that is acceptable for the monitoring unit. The issues of data abstraction within computation of derived values, data validation, and conversion of results in qualitative information (Miksch and Seyfang, 2000).

The monitoring unit bridges the gap between the data abstraction unit and the execution unit. It acquires a parameter from the data abstraction unit and gathers them in a list of observed parameter propositions (OPPs). Besides, it defines a list of temporal standards, named monitored parameter propositions (MPP). MPP used for future state transitions of instantiated plans.

The execution unit map plans and real problem in the environment. It consists of three different layers forming the plan synchronization, plan adaptation, and re-planning. All plans have time annotated conditions for denoting temporal constraints on the plan duration in plan synchronization. The plan execution is terminated until its failure is definitely observed or its objectives are reached. Plan adaptation function as plan suspension and plan replacement. Re-planning can happen for other users' requests and the failure of the plan. The execution unit searches for plans either have effects that remove the cause for the failure of the current plan or have the same intentions if a top-level plan fails.