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Optimized Diet Plan using Unbounded Knapsack Algorithm

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***Abstract*—Cholesterol, hypertension and diabetes are the three major chronic diseases from which most of the people suffers and these peoples often use search engines to acquire related information about these problems. But, almost every information related to diet on the internet isn't suitable for people to gather information about the diet suggestions. A system for diet suggestion which can advocate a prudent diet for such peoples is suggested in this paper. We designed a system that recommends a proper diet which has the adequate knowledge of three above mentioned highly chronic diseases. We propose a solution to the menu recommending problem using the optimization algorithm known as unbounded knapsack. We designed a model which satisfies the nutritional requirements of individuals while imposing the "Laws of Nutrition", a set of hypothesis used by almost all Latin America's nutrition scientists. This prototype corresponds to a numerical optimization problem with constraints. We design a menu items generator application model to set up a convenient menu for a user with different properties.**

***Index Terms*—planning,diseases,optimization,guideline,dataset, diabetes,macronutrients.**

I. Introduction

Along with bringing people ample of foods, wealthy life brings a high chance of growing certain diet related diseases. Unbalanced diet is the reason for most of the people suffering from chronic diseases like diabetes, hyperlipidemia, and cholesterol etc [6]. So people need to give careful consideration to their health conditions and they should know accurate information including how to prevent from disease, what to include in a diet as a healthy food and curing such diseases. Although, some of the diseases are not easily curable, like diabetes which not just depends on drug treatment but also on dietary control over long term to decrease disease's injury. High cholesterol, hypertension and diabetes leads to the 10 topmost death causes. In the rundown of reasons for death, disease related to high cholesterol such as disease of heart, cerebrovascular illness, diabetes, hypertensive diseases ranked second, third, fifth and ninth, respectively. In country like Taiwan, the number of elderly individuals suffering from "three high chronic diseases", which are high cholesterol, hypertension and diabetes is more than 60% [2]. In fact, controlling these diseases is possible with the use of proper diet intake. Therefore, prudent diet plays most vital role in achieving healthy life. Although it is a meaningful work, until now there are very less researches that focuses on recommendation of diet.

In this paper, a diet recommendation system is suggested which can recommend a prudent diet for individuals. This system deduces suitable diet by taking into consideration two parameters: age and gender. Oftentimes, people choose a meal based on a particular goal. For example, a person may want to maximize the amount of protein they eat in a meal while not surpassing the amount of calories and fat consumed. This study investigates this type of problem by formulating the problem as a Unbounded Knapsack Problem, which can be solved using a strategy called greedy approach.

This paper is organized as follows, section II describes Literature review on this problem, section III describes the problem description and different constraints to be used, and solution for the problem is explained in section IV, section V shows experimental results and its analysis, the last section i.e. section VI includes conclusion that can be drawn from the problem and its specified solution.

II. Literature Review

According to Andrew Emerson in "The Knapsack Problem: An Implementation in the Furman Dining Hall" [1] such a task of diet recommendations can be solved by using 0/1 Knapsack Algorithm. The Furman University Dining Hall uploads its daily menu on a website, where it lists nutritional values for each item. For example, a cup of rice(100gms) contains 7.7% protein, 0.015% calcium, 0.68% phosphorous, 78.2% carbohydrate and overall 345Kcal of energy. Various food items have different amount of nutritive value in them, some rich in a particular factor or deficient in another. After extracting the appropriate data to a text file, greedy approach may be used to optimize the items. In the text file, the list of food items also lists the protein and caloric content (for one serving).

Different food items described in menu have different calorific values. Each food item is specific for the amount of protein, fat and carbohydrate it contains. For an instance, a boiled egg contains 90Kcal of energy and the protein content is 6gms (approximately), that's why considered reference protein. In order to comply with a 0/1 formulation of the Knapsack Problem, the optimized solution will determine whether or not to take a single serving of a given food item [5]. It helps in choosing the described amount of diet a person needs in his day to day life. The energy requirement one has determines the person's food intake. In its further study it is mentioned that this could be further investigated for maximizing the protein without surpassing the fat intake. Food items like meat, egg and other animal products which are rich in both protein and fats should be advocated. It will help in increased intake of protein without compromising with the fat levels. We attempted to solve this problem in this paper.

NHMRC(National Health Medical Research Council), on the basis of fraternizing studies conducted by countries like Australia & New Zealand, has defined RDI i.e The Recommended Diet Intake, to be the average daily dietary consumption level of necessary nutritional needs of fit & healthy persons that includes micro-nutrients, minerals & vitamins. It is necessary to get the knowledge in order to assess the nutritional adequacy of diets for different group of people according to described need. Food items are kept in diet according to requirement.

Obviously, finding a meal which satisfies the taste buds, appetite & itself has all the necessary requirement which makes it nutritionally balanced is really hectic and cumbersome process. Here comes the concept of balanced diet or optimum diet. Balanced diet is one which contains variety of food in such amounts and proportions that the need of energy, amino acids, vitamins, minerals, fats, carbohydrates and other nutrients is properly met for maintaining health, vitality and general well being and also makes a stock for extra amount of nutrients to withstand short duration of leanness. It is the most accepted theory to safeguard people from nutritional deficiencies.

The RDI's is a rule only, one has to set the daily intake of food levels such that the nutrient requirement are met within an optimized level of diet.

Such a problem lacks specificity for the reasons:-

(a) Lacks of solution which is accurate.

(b) Nature of choice and

(c) Difficulty due to same menu dishes containing varieties of nutrients meeting aim & those having limitation.

Let, for instance a particular food is rich in proteins, fiber but at the same time can be high in cholesterol which is not desirable. RDI doesn't gives any idea about minimum sugar consumption requirement, so any amount of sugar intake is considered as deflection. High cholesterol diet may precipitate coronary heart disease and obesity while increased sugar intake may lead to diabetes syndrome.

Some of the nutrients , have also a maximum average daily nutrient intake known as Upper level Intake(UL) limits. It is the highest daily nutrient intake level that is likely to pose no risk of adverse health effects for almost all individuals in general population. Doses above it, may be potentially harmful. RDI, suggest many important nutrients & dietary energy, out of which 8 are chosen for this study. The nutrients Reference Value(NRVs) for some 3 nutrients among 8 dietary energy are taken as the analysis criteria for demonstration. These are numbered from X1 to X3.

1) Calorie(X1) includes the nutritional details of dishes including the total dietary energy that could be gained by consuming that item.
2) Protein(X2) is a macro-nutrient needed for the human body & 20%-25% of total energy is obtained from protein varies from person to person & lifestyle also.
3) Total fat(X3) provides the supply of total energy. It gives 25%-35% energy from the diet.

III. Problem Description

This paper deals with optimization of diet plan with unbounded knapsack algorithm which can take more than one instance of any item [4]. When we wish to select food items in our daily life, we come across varieties of food items, we are unable to decide upon the selection of which items to cook or to order from restaurants which satisfies the day to day nutritional needs and user's requirement depending upon the person"s age, gender and choices. As choices plays a major role in deciding what amount of protein we can get. Maximum amount of consumption of protein helps a person in a healthy diet and preserve themselves form the various diseases. If improper choices are made while selecting food items, proteins may be increased but along with that we are in a risk of excess of cholesterol and fats which are in turn harmful for the health. Thus, we should take utmost care such that we should consume more protein without surpassing the calorie and fat limits. Every human being has the limit on maximum requirement of calorie and fat per day. These requirements depends on various physical factors like age, gender, height, weight, activity, etc. We have considered two of these parameters age and gender.

IV. Solution Proposed

This section describes briefly the proposed algorithm i.e. unbounded knapsack algorithm for solving the above described problem of diet planning. We consider table 1 given below as a universal data set which contains all the possible food items which can be available either in a restaurant or those we preferred to cook. Here, we have taken Indian dishes as the example, which can be changed according to places and items available in that particular region. Table 1 contains dishes name, their calorie content per 50gms, fat content per 50gms, protein content per 50gms. Reason for taking per 50gms is that we assume that any dish has to be served at least 50gm. Any item cannot be served less than 50gms. We can categorize each food items depending upon the maximum amount that can be served. This categorization is not a hard fact and depends upon food items and understanding of a person categorizing them. For sake of simplicity here we categorise the food items into four categories namely: Item that can be consumed 100 gms, 150 gms, 200 gms, 250 gms as shown in the table.

It's not necessary that we select all the food items that we mentioned in table 1. The items we select is the subset of table 1 for optimizing our diet plan over this set. The main aim of this algorithm is to maximize protein intake without surpassing the calorie and fat consumption limits per day of a person. Now let all the items in table 1 are given as a choices to user. From them user selects some of the dishes, say set S is the selected choices. As in the knapsack, we need the

Dish	Calorie(per 50gms)	Fat(per 50gms)	Protein(per 50gms)	Category
Veg.Biryani	58.57	2.15	1.24	4
Dum Aloo	264.0	7.09	6.5	3
Palak Paneer	56.27	7.5	2.41	2
Dal Makhani	84.18	1.66	3.31	3
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
Mutton Biriyani	79.85	4.625	4.72	4

Table 1: The dataset table

maximum Calorie and Fat consumption for a day say C and F. This C can be determined by using table 2 below(depends of physical conditions of person).

Age	Gender	
	Male	Female
0-5	1300	1250
6-10	1680	1600
11-20	2540	2020
21-30	2700	2100
31-40	2600	2000
41-50	2500	2000
51-60	2400	1800
61-70	2300	1800
>70	2200	1800

Table 2: Calorie Chart

The value of Fat is about 25% to 35% of the calorie value. Here, we take fat as 30% of the calorie value. Thus, F can be calculated as:

$$F = 0.3 * C \tag{1}$$

We are using unbounded knapsack as we can use one and more instances of particular dish items. Thus we get any item selected which is 50gms or multiple of 50gms. Given a set S of 'n' items having calories $\{C_1, C_2, C_3, \ldots C_n\}$, Fat $\{F_1, F_2, F_3, \ldots F_n\}$ and Proteins $\{P_1, P_2, P_3 \ldots P_n\}$ and a Knapsack of calorie and fat capacities, C and F respectively. Finding the maximum value that can be accommodated using one or more instances of given calories. So, the aim is to maximize the value of protein of picked up items such that sum of the calorie is less than or equal to C (Knapsack Weight) and also sum of the fat is less than or equal to F(another knapsack weight). Such an algorithm are as given below:

Algorithm 1: Driver()

```
Initialize LIST, CALORIE, PROTEIN, FAT,
  CATEGORY
Display LIST and ask user to input choices, age and
  gender
Take the choices and store in another array LI
Store respective calorie, protein, fat and category in
  arrays CAL, PRO, FT and CAT respectively
Initialize C depending upon age and gender and table 2
Calculate F = 0.3*C and size s=LI.length
Call DietRecommend (LI, CAL, FT, PRO, CAT, C, F,
  s)
```

Algorithm 2: DietRecommend (LI, CAL, FT, PRO, CAT, C, F, s)

```
Initialize each element of array INSTANCES1 and
  INSTANCES2 of sizes s to 0
Initialize PRO2 = PRO, LI2 = L1, CAT2 = CAT
Calculate RATIO1 as PRO/CAL for each element
Sort RATIO1 in descending order. Also sort
  corresponding LI, CAL, PRO and CAT
Initialize c=0.0,p=0.0,totalProtein=0
Repeat for i=0 to s
    Set value of k according to the value of CAT[i]
    Repeat for j=0 to k
        If(CAL[i]+c<=C) then
            Increment INSTANCES[i]
            c= c + CAL[i]
        Else increment i and break
Calculate RATIO2 as PRO2/CAL2 for each element
Sort RATIO2 in descending order. Also sort
  corresponding LI2, FT, PRO2 and CAT2
Repeat for i=0 to s
    Set value of k according to the value of CAT2[i]
    Repeat for j=0 to k
        If(FT[i]+p<=F) then
            Increment INSTANCES2[i]
            p= p+ FT[i]
        Else increment i and break.
Calculate the value of totalProtein if the item is present
  in both the lists LI and LI2 when their instances are
  not 0 and taking the minimum instance of the two
  and choosing appropriate PRO or PRO2 accordingly.
Display the items thus used in above step and its
  respective instance * 50.
Display message "You can consume "+totalProtein+"
```

Here, value of k decides upon the maximum number of instances to be taken of a particular item. Suppose k=2 for an item say "XYZ" then that item can be taken 100gms or 50gms or 0gms (i.e. it is not selected at all). Any item cannot be selected except the multiple of 50gms. This can be varied by changing the categorisation and values of k accordingly. Also the dataset has to be modified accordingly.

V. Experimental Results and Analysis

The above algorithm has been implemented by simple java application. Fig 1. shows the inputs of age, gender and items to be considered and fig 2. shows the output i.e. items thus selected by the above algorithm which is an optimised result which do not surpasses the calorie and fat than the maximum need of a human being and maximizes the protein intake whose value is as shown in figure.

For an instance, let's consider that user enters age as 26 and selects gender as male. For these the calorie and fat limits can be set as mentioned in the Table 2 and Formula 1, respectively. In addition to this, user selected 15 dishes which he wishes in his diet. All the dataset i.e. calorie, fat, protein, category value of all the 40 dishes shown are already stored in a database used

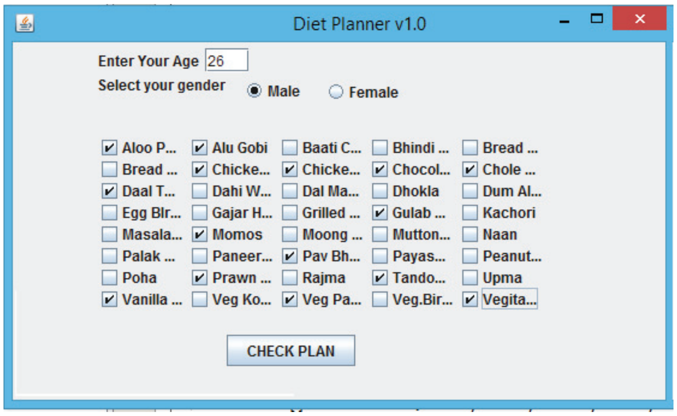

Fig. 1. Input from the User

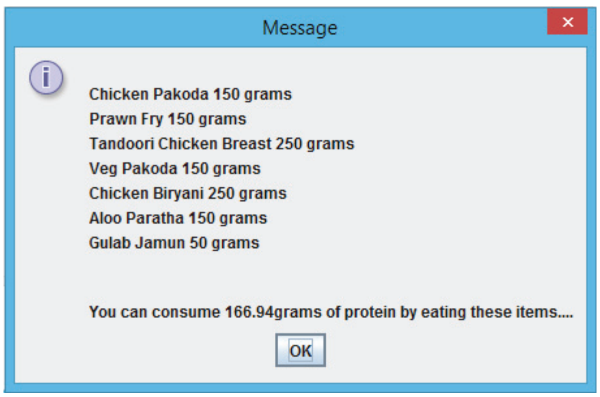

Fig. 2. Output i.e optimized result

in backend. So, in figure 2, the output of the above algorithm is displayed i.e. 7 items out of 15 are selected which gives the optimal value of protein i.e. 166.04 gram. We consider existing algorithm to be 0/1 knapsack, as used by Furman Dinning Hall problem [1]. If we use 0/1 knapsack the major disadvantage is that we can select at most one instance i.e. item may be either selected or not. Thus, we can get only 50gms of a dish or 0gms(as we are considering 50gm to be the minimum amount of serving any dish). We can never get a dish more than 50gms. In unbounded knapsack, this can be achieved by the concept of multiple instances of the same item. Thus, using 0/1 Knapsack may sometimes seems to be irrelevant whereas unbounded knapsack overcomes this disadvantage of the 0/1 knapsack. We can think of using fractional knapsack [3] instead of 0/1 knapsack. But the problem here is that, it is somewhat similar to 0/1 knapsack except that the remaining knapsack is filled by choosing the next optimal item. So disadvantage of 0/1 knapsack cannot be removed by using fractional knapsack. Another issue is that, only fraction of last item is taken which can be so small that it can seems to be irrelevant(consider if 3gms of any item is selected). Thus, choosing the Unbounded Knapsack for such a problem can not only gives us an optimal but also a relevant solution.

The two algorithms Unbounded knapsack as well as 0/1 knapsack both have the same worst case time complexity i.e. O(n*W), where n=number of items considered, W= total capacity of the knapsack. So, from a time complexity point of view, we don't benefit from using unbounded knapsack in our implementation. The only benefit that we obtain is that the unbounded knapsack is more suited to our application, as it will allow us to take more than one instances of the same item.

VI. Conclusion

As health is the major and most important concern for every human being, awareness about healthy nutrient profile is the primary way of preventing oneself from diseases. Nutritional knowledge should be acquired by every person. Healthy diet is one among the many factors that are the part of nutritional knowledge. Thus, diet planning becomes a basic approach towards achieving a healthy life. For this, proper recommendation of dishes to be included in one"s meal is an important task. With a user-friendly interface, a person can execute a healthy diet with only a limited understanding of the nutriological background and dietetics since optimized diet plan can translate nutrient recommendations into realistic individual food choices. The diet formulation which is an optimize problem can be successfully implemented using greedy approach model. As an aspect of an interdisciplinary research, an effective algorithm which uses unbounded knapsack is developed and its relevancy is demonstrated with a related example, as the problem of diet-planning belongs to the multidimensional knapsack problems. For instance, instead of looking at protein, calories and fat, the algorithm could maximize the fibre intake while not surpassing a certain carbohydrate intake. In future, we can make this application more personalized and efficient by introducing user oriented details such as BMR, BP levels, need of amount of particular nutrient. We can make use of other bio-technical devices and test results stating the deficiency of nutrients in one's body in association with such an application to make diet more precise and effective. Essentially, this investigation shows that it is possible to formulate food optimization into an Unbounded Knapsack Problem.

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