A Mathematical AI-Based Diet Analysis and Transformation Model

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Abstract Inadequacies in nutritional intake can be considered as a major source of adverse effects on the growth and health of individuals in India. A proper balanced diet is essential from the very early stages of life for proper growth, development, to remain active and to reduce the risk of diseases. For those with diabetes, a proper diabetes diet is crucial which depends upon their energy requirements. So a need has been identified to develop educational software which should perform the routine task of analyzing, optimizing, and transforming diet by considering their energy requirements and medical problems. The different nutritional values present in a diet are generally affected by imprecision, which can be represented and analyzed by fuzzy logic. For diet balancing, a metaheuristic local search algorithm is proposed which works in a local search space recording the history of search to make it more effective and optimized. These proposed methods will help users to improve their nutritional intakes by providing detail analysis of their food intake, by providing an optimized diet plan and by suggesting possible changes to make their diet suitable according to their energy requirements.

Keywords Energy evaluation · Fuzzy interval · Tabu search · Mathematical AI model

1 Introduction

Inadequacies in nutritional intake can be considered as a major source of adverse effects on the growth and health of individuals in India. The common nutritional problems in India are malnutrition, low birth weight, chronic deficiency in adults, and diet related noncommunicable diseases [1, 2]. To maintain health and increase

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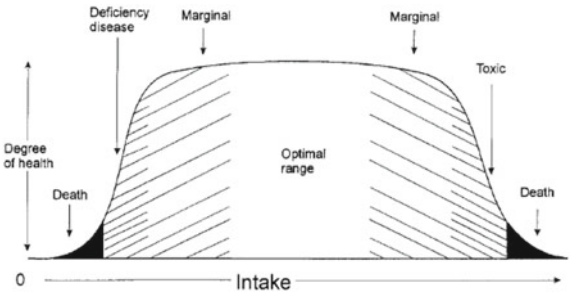

Fig. 1 Degree of health

life expectancy and to decrease the frequency of cardiovascular diseases, one has to improve its dietary habits which is based on the nutrition values. Thus, a need has been identified to develop educational software which will monitor and perform the daily task of analyzing, optimizing, and correcting the user's diet at home.

The nutrition intake can be appropriately evaluated and described by employing fuzzy sets and fuzzy arithmetic. Wisram [3] evaluated the nutritional intake status assessment by comparison of intake with the official recommendation for that person. Figure 1 shows the degree of health when varying the intake of one essential nutrient and holding the rest of the diet constant at an optimal level [3].

The work proposed in this paper focuses on the development of interactive AI-based mathematical functionality as an effective solution to support continuous nutritional management. Firstly, we will discuss the general problem statement, and then, the criteria for energy evaluations are described in Sects. 4, and 5 defines some preliminaries on fuzzy sets and fuzzy interval. The background of tabu search is discussed in Sect. 6, and finally, the integration of all these sections, i.e., a proposed work is described in Sect. 7.

2 Problem Statement

A problem exists regarding the inaccurate values of nutrients in foods because the approximate amounts of nutrients available in a certain food are normally known, but there is always a question of their exact amounts. There is often a problem of imprecision with the nutrient values, i.e., their exact amount [4, 5]. This problem may increase if only partial information is available especially for industrially processed foods, but for precisely packed foods (for instance Cheese, Butter, oil, rice, biscuits, etc.), we can obtain the nutrients value precisely. For other foods, for instance vegetables and fruits (banana, apple, etc.), nutrients values varies in a large range, depending on size, growing conditions, freshness, etc.

All this values, i.e., precise and imprecise, have to be stored in a database, and a computer then needs to operate on these values. It should be able to compare these values and should perform all the arithmetic operations [1, 4, 5].

3 Energy Requirements and Its Evaluation

The amount of each nutrient needed for an individual depends upon his/her age, body weight, and physiological status which can be calculated in terms of energy [2].

RDA recommends that energy requirement must be assessed in terms of energy expenditure rather than in terms of energy intake.

$$\begin{aligned}\text{i.e. Total Energy Expenditure} &= \text{Predicted Body Mass Ratio} \\ &\times \text{Physical activity level (PAL)} \end{aligned} \quad (1)$$

Physical activity ratio values for activities performed in a day can be aggregated over that period to yield the physical activity level (PAL). A detailed table of PAR values for different activities is available in the FAO/WHO/UNU 2004 report [2].

3.1 Nutrients Consideration

The primary macronutrients which are important and are considered are protein, fats, and carbohydrates which are converted into energy in different quantities, i.e., 1 g of protein contribute 17 kJ of energy, 1 g of fat constitute 37 kJ of total energy, 1 g of carbohydrates contribute 17 kJ and 1 g of dietary fiber contribute 8 kJ where 1 kJ = 0.239 kcal [3].

4 Fuzzy Arithmetic and Computation

4.1 Preliminaries

In this section, we review the fundamental notions of fuzzy set theory.

Fuzzy Interval. **Definition 1**. A fuzzy interval is a fuzzy set [6] of real numbers, written M, having membership function μ_M.

$$\forall \alpha \in [0,1]\, M_\alpha = \{r|\mu_M(r) > = \alpha \quad \text{(the a-cut of } M\text{) is a closed interval.} \quad (2)$$

support $S(M) = \{rj\mu_M(r) > 0\}$ is the largest membership area of x (x cannot take a value outside $S(M)$), whereas the kernel $\dot{M} = \{r|\ \mu_M(r) = 1\}$ is the set of the most plausible values for x, also called modal values, and membership function is unimodal and upper semicontinuous [6].

Fuzzy Computation. Extension principle [7, 8] is used for performing basic arithmetic operations on trapezoidal fuzzy numbers. Let M and N be two fuzzy

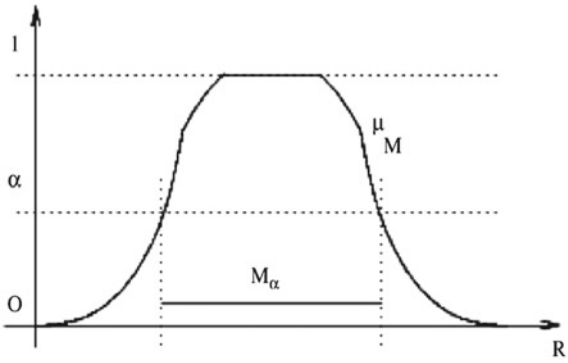

Fig. 2 Fuzzy interval

trapezoidal intervals ($\underline{m}_1, m_1, \alpha_1, \beta_1$) and ($\underline{m}_2, m_2, \alpha_2, \beta_2$), respectively. Addition and subtraction on M and N is given by [7, 8] (Fig. 2).

$$\begin{aligned} M+N &= \left(\bar{m}_1+\underline{m}_2, \bar{m}_1+\bar{m}_2, \alpha_1+\alpha_2, \beta_1+\beta_2\right) \\ M-N &= \left(\bar{m}_1-\underline{m}_2, \bar{m}_1-\bar{m}_2, \alpha_1+\beta_2, \beta_1+\alpha_2\right) \end{aligned} \tag{3}$$

5 Tabu Search Background

Classical methods encounter great difficulty in solving hard optimization problems.

In several cases, we need a modified heuristic approach which provides a solution very close to optimality that tackles the difficult problems at hand and improves the computing time of local search techniques. The metaheuristic approach called tabu search (TS) was proposed by Fred Glover in 1986 to overcome local optima, which is now dramatically changing our ability to solve problems of practical significance [9, 10].

Tabu is an intelligent search process which incorporates adaptive memory and responsive exploration (an intelligent search) [11, 10]. Tabu search can be applied directly to many kinds of decision problems, without the need to transform them into mathematical formulations.

6 Proposed Work

The proposed AI-based mathematical model comprises three modules, viz. analysis module which helps the user to know the nutrients present in the selected diet and its amount. The second module is an optimized module, which gives the perfect diet planner considering the user's medical problem, and lastly the transformation module which can make small changes in the user's diet to make it well balanced while considering the requirements and possible medical problems.

6.1 Diet Analysis Module

A record for each patient is created which contains his/her physical parameters, level of physical activity, and possible medical problems. Considering these entire parameters, energy requirement is calculated by considering Eq. (1). The user is then allowed to choose a food present in a hierarchy and enter the portion for evaluation which gives the correct assessments and suggestions. This evaluation is done by using fuzzy interval which is trapezoidal mentioned in Sect. 4.1. After computing the total energy, it is compared with the prescribed norms, in order to assess whether it is compatible. Let norms and data, represented by the possibility distributions P and D, respectively. Degree of possibility of matching and degree of necessity of matching are given by $N(P, D)$ and $\pi(P, D)$

$$\pi(P, D) = \sup \min\left(\mu_p(\mu), \mu_d(\mu)\right), N(P, D) = 1 - \pi(P, D) \tag{4}$$

The result of which is displayed to the user by using interfacing techniques.

6.2 Optimization Module

The food database consists of some diet plan based on different energy requirement prescribed by nutritionist. This diet plans gives total say n combinations. A measurement of appropriate energy and nutrient intake with a respect to the recommendations, or optimal intake, is evaluated by metaheuristic search logic which is further displayed in decreasing order. Optimization solutions provide assistance in the selection of a better diet plan. This module is adaptive in nature as it enhances its diet combinations from transforming module and increasing its efficiency.

6.3 Diet Transformation Module

This module aims at telling the user how he/she may modify his/her diet to make it according to his/her energy requirements and adapted to his/her possible medical problems. It is indeed a difficult task for the user to perform certain modification in their diet to make it well balanced as modifying the weight of a food, for instance, often leads to have the transformation of several nutrients modified at the same time. The diet provided by the user generates a state space which can be solved by applying minimum transformation using an algorithm. Let us assume that for each diet m in "generated diets," the following is known:

- The minimum cost of transformation from the initial diet m to noted g;
- An estimation of the cost to transform m to its closest solution g.

Proposed Transformation Algorithm 1.

```
1. Consider the initial diet m
2. searchList is empty.
3. While the stopping criteria is not satisfied do
    Check the value of meal according to energy
requirement .Generate diet m's neighbors by applying
transformations Operations by considering history and
constraints.(i.e. m')Then compute evaluation term f = g+h(goal
amount)
4. m - > m'
5. Update the search list.
6. End and return the best solution met.
```

From the above mention algorithm, a specific diet plan is generated by evaluating the required energy requirement and by applying small changes.

7 Concluding Discussion

The AI-based mathematical model for diet optimization and transformation solves the common nutritional problems of public health problems in India using fuzzy arithmetic and a search space metaheuristic algorithm.

Imprecision of data is represented by fuzzy sets, whereas fuzzy arithmetic provides all the necessary computations on these values, which are then compared with the prescribed values present in a database and can be shown to the user by using suitable interfacing techniques. A diet optimization module discussed in Sect. 6.2 gives best diet plan available according to the user's energy requirements. The contents of the daily diet BLSD (breakfast, lunch, snacks, and dinner) are already stored in the database which can be selected on the basis of constraints, preserving their eating practices by using local search metaheuristic algorithm. Finally, the proposed transformation algorithm balances the diet by developing the state space, considering the needs of user and applying minimum possible changes.

For the future, we intend to deal with optimizing diet, based on cost (price) as an additional objective function. It would enlarge the state space of metaheuristic search algorithm and would greatly help in finding more optimized solution.

Declaration

The consent from patient is not required in this paper as no patient is physically involved in this study (or during analysis). The data collected during this study are from right resources.

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