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Personalized Meal Planning for Fitness Goals Using Linear Programming and Machine Learning

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Abstract
Now a days young ones are more health conscious and hence they prefer to go to gym for body workouts to achieve their fitness goals. In order to achieve these goals, they need a balanced diet which consist of macro nutrients, micronutrient, and caloric intake. The proposed research uses Simplex Method which is a linear programming optimization technique along with machine learning model to create enhanced model which is scalable and customized dietary framework for gym-freaks. The proposed model works with Simplex Method which helps in optimizing meal plans under constraints like caloric needs, cost, and dietary preferences and machine learning model will help in predicting user-specific requirements based on various factors like BMI, activity levels, and fitness goals.

Keywords: machine learning, optimization, simplex method, balanced diet.

1. Introduction

1.1. Background

Today's world has become very fast and challenging with lots of pressure and workload along with deadlines. People may not get enough time to eat or to have a balanced diet including proper sleep. Due to which there are lot many health issues which are triggering at an early age. Many people are struggling in gaining muscle or fat loss or some recovery. Therefore, people started opting for gym. But along with gym a proper balanced diet is needed which can help them to achieve goals. The traditional approach lacks in providing personal touch along with dynamic change in dietary needs. Hence a proposed optimization technique like Simplex Method along with Machine Learning model can bridge this gap.

. Diet planning and research finds the relationship between health and healthy eating habits among individual ones. Diet is what is important to enhance growth in terms of muscle and preventing diseases. The research based on these concepts are dependent of Machine Learning algorithms in terms of prediction and diagnosis.

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1.2. Machine Learning

ML is a subset of AI focusing on algorithms to solve a complex task by learning patterns of data rather than hard core program. One can achieve this by defining an objective i.e. predicting a value and evaluating performance to optimize model. Basically ML is nothing but creating and implementing algorithm that helps to take decisions and predictions. There are three types of ML techniques which are nothing but supervised learning, unsupervised learning and reinforcement learning.

1.3. Operation Research

Operation Research is an approach which uses scientific technique with which one can analyze problems and make strategic decision. It uses mathematical modeling with data analysis and further it tries to optimize results for complex problems. Mathematical model represents a core of real world problem representing simplifying techniques for resource allocation, transportation and optimizations. The job of OR is to find the best feasible solution so as to minimize or maximize the cost, time, energy etc. depending on constraints. OR integrates various tools and methodologies from various sectors like mathematics, statistics, computer science, engineering etc. Methods used in OR are versatile and widely applicable, making it an indispensable discipline for decision-makers across various industries. By integrating mathematical rigor with real-world practicality, OR bridges the gap between theory and application, ultimately driving innovation and efficiency.

1.4. Problem Statement

In order to create a balanced diet consists of satisfying variety of constraints consisting of macro nutrient distribution, calorie requirement, and budget. The diet plan should have capability to adapt to the unique metabolic and activity-related variations of individuals. That implies the model should designed in such a way that it can customize the requirement. the existing methods are unable to provide such solutions and involves complexity.

1.5. Objective

The research paper proposes a simplex method to optimize balanced diet based on various constraints. Adopt machine learning model to customized recommendations by integrating with operation research.

2. Literature Review

In this current era researchers are working with multiple techniques which can be applied on various problems associated with diet system and help people to choose their diet plan based on daily needs of food. Researchers are also working on medical history and other preferences. Exhaustive review of papers will showcase the research gaps in following papers. Healthcare and Dietary Recommender Systems

Thi Ngoc Trang Tran et al. (2021) emphasized the broad applications of recommender systems in healthcare, such as nutrition, medication plans, and health services. Their research highlights the methodologies and proposed scenarios for system implementation, including real-world examples to enhance practical understanding. Similarly, Wenbin Yue et al. analyzed traditional recommendation methods like content-based and collaborative filtering, as well as hybrid systems. Their work underlines the potential of these methods in areas such as dietary and lifestyle recommendations, along with patient and physician decision-making processes.

PersonalizedNutritionFrameworks

Jun Gao et al. (2017) proposed a personalized diet system using Bayesian personalized ranking and matrix factorization, demonstrating improved performance over traditional collaborative filtering techniques. Additionally, Anonnya Banerjee et al. developed the Nourishment Recommendation Framework tailored to children aged 8-13, considering their developmental needs and medical history. This framework exemplifies the potential of machine learning to generate age-appropriate dietary plans.

Nivetha et al. (12) emphasized the role of supervised algorithms like support vector machines (SVM) and decision trees for classifying diet plans into balanced or unbalanced categories. Random forest classifiers and k-means clustering were used to analyze user attributes, such as physical activity and nutritional needs, enabling tailored recommendations

Yilmaz (10) integrated OR techniques with ML models to optimize multistage decision-making in diet planning. The study used prediction-optimization frameworks to solve dynamic optimization problems, significantly reducing computation time without compromising solution quality. These approaches enable real-time dietary adjustments, ideal for fitness enthusiasts.

Studies like MOFit (11) leveraged IoT with ML to provide continuous monitoring and feedback. Decision trees and gradient boosting algorithms optimized diet plans based on real-time IoT data, ensuring precise caloric balance and nutrient distribution

3. Research Methodology

In the fitness world, the importance of a balanced diet cannot be overstated. For gym enthusiasts, achieving fitness goals such as muscle gain, fat loss, or improved endurance requires a diet plan that carefully balances all essential nutrients. To design such diet plan is a complex task therefore the proposed paper shows the integration of machine learning and simplex method to optimize the diet plan. Machine learning excels in analyzing vast datasets and identifying patterns, making it an ideal tool for predicting individual dietary requirements based on factors such as body composition, activity level, and fitness objectives. Meanwhile, the simplex method—a well-established mathematical optimization technique—provides a systematic framework for determining the most efficient distribution of resources to meet multiple constraints and objectives. When combined, these approaches offer a powerful solution for crafting personalized and optimized diet plans for gym enthusiasts. This study explores the integration of machine learning and the simplex method to develop a novel approach to dietary optimization. By leveraging machine learning to predict personalized nutritional needs and applying the simplex method to allocate macro nutrients and caloric intake efficiently, this framework addresses the unique challenges faced by fitnessfocused individuals. The proposed method not only enhances the accuracy of diet plans but also ensures adaptability to changing goals, preferences, and dietary constraints. By bridging the gap between advanced computational techniques and practical diet planning, this approach has the potential to revolutionize nutritional strategies for gym enthusiasts, enabling them to achieve their fitness goals more effectively and sustainably.

4. Proposed Flow Model

The figure indicates the proposed model which is a blend of machine learning and simplex algorithm for recommending diet plan to gym going people. Data has been collected from various sources which includes Body metrics, Fitness goals, Dietary restrictions or preferences, Historical diet data. Here , the research was done with the help of supervised learning algorithm. The

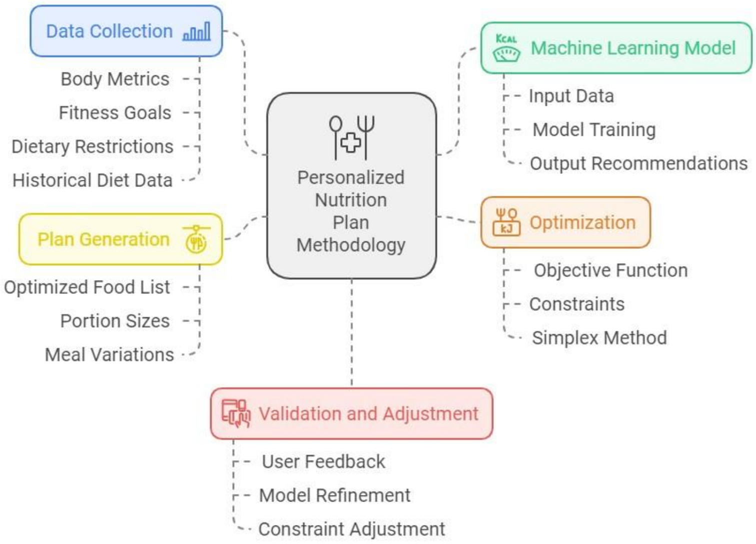

Figure 1: Proposed Flow of model

model was trained using random forest , neural network to predict the correct need of nutrient food. The goal of research paper is to minimize the total cost incorporated or maximize the nutritional value of the diet while meeting fitness goals. There are predefined intake specified for all nutrients in the form of proportion 40:30:30 i.e. carbs:protein:fat respectively. Some constraints are specified based on individual plan. The simplex method calculates the optimal combination of food items to achieve the desired nutrient distribution within the established constraints. The combined optimized food list will generate meal plan for the entire day. User feedback will be considered by the system to improve upon the objective function and hence selection of another plan.

4.1. Data Collection

The data for this study was collected through a various techniques such as primary and secondary methods to ensure a comprehensive analysis. Primary data was gathered through online surveys administered to a sample of 200 participants, selected using a stratified random sampling technique. The survey included both closed and open-ended questions to capture both quantitative and qualitative data. Additionally, secondary data was obtained from publicly available industry reports and academic journals, which provided contextual background and supported the analysis of current trends. The data collection process spanned a period of three months, from June to August 2024, and was conducted in compliance with ethical standards, ensuring participant anonymity and informed consent. Hence exhaustive data has been collected from various people who prefer to go gym in the Mumbai region. The table shows column details with description. Various parameters are taken into consideration which helps us to understand the structure and significance of the dataset, making it easier to analyze or process the data for fitness tracking, reporting, or visualization purposes. The data sets consists of various parameters like meal type, food name, intake of fat, fiber, sugar, protein, carbs etc. The detailed description is also provided along with the caption.

Column Name	**Description**
Meal Type	The type of meal (e.g., Breakfast, Lunch, Dinner, Snacks).
Food Name	The name of the food item.
Serving Size	The amount of the food consumed (e.g., 1 cup, 100 grams).
Calories	Total calories in the serving.
Carbohydrates	Carbohydrates content (grams).
Protein	Protein content (grams).
Fat	Total fat content (grams).
Fiber	Fiber content (grams).
Sugar	Sugar content (grams).
Sodium	Sodium content (milligrams).
Saturated Fat	Saturated fat content (grams).
Exercise/Activity Data	

Date	The date of the exercise.
Exercise Name	The type of exercise performed (e.g., Running, Swimming).
Duration	Duration of the exercise (minutes).
User Metrics	
UserID	Unique identifier for the user.
Weight	User's weight (typically in kilograms or pounds).
Height	User's height (centimeters or inches).
Age	User's age.
Gender	User's gender.

Table 1: Gym Data set

4.2. Simplex Method

The Simplex Method is a one of the operation research technique widely used in linear programming for solving optimization problems. Here the objective is to maximized or minimized the cost subject to a set of linear constraints. The method evaluates the objective function at the current vertex and choose the neighboring vertex that improves the objective function value, either increasing or decreasing it, depending on whether the problem is a maximization or minimization problem. This process continues until the algorithm reaches a vertex where no further improvement can be made, indicating that an optimal solution has been found.

4.2.1. Formulation

The proposed model for a diet system talks about maximizing protein intake and minimizing cost.
Let us define variables.
LetXibethequantityoffooditemiwherei = 1*ton*∀*X*
Pi ∈ *Proteinintake*
Ci ∈ *costperunitoffood*
Dj ∈ *calories*
Ej ∈ *carbs*
V i ∈ *V itimine ObjectiveFunction*
The goal is to maximize protein intake while also minimizing the cost. The objective function can be written as:

Maximize: $Z = \sum_{i=1}^{n} P_i X_i - \sum_{i=1}^{n} C_i X_i$

constraints

$\sum_{i=1}^{n} Di * Xi$ = Cal Requirement (CR)
$^{Pn}i{=}1\ Ej * Xi <= 0.5 * CR$
$^{Pn}i{=}1\ Pi * Xi >= 0.3 * CR$
$^{Pn}i{=}1\ V i * Xi >= 0.2 * CR$

Framing the Minimizing cost function by considering all constraints
Mini Z =c1x1+c2x2+c3x3+.....+cnxn Sub to $a11x1 + a12x2 + ... + a1nxn >= Dj$ $a21x1 + a22x2 + ... + a2nxn >= Pi$ $a31x1 + a32x2 + ... + a3nxn >= V i$

4.3. Machine Learning

A Machine Learning (ML) model for optimizing balanced diets for gym enthusiasts focuses on predicting and recommending personalized nutrition plans based on individual factors such as age, weight, training intensity, fitness goals, and dietary preferences. Following are the models that can be used to predict the pattern. The research paper uses Decision Tree and Clustering algorithms. The goal of using a decision tree is to predict the most suitable diet plan for a gym enthusiast based on their attributes such as age, weight, body type, and fitness goals. Using labeled data decision tree splits into various features like fat percentage, exercise etc.

4.3.1. PseudoCode- Decision Tree

1. Load the complete dataset
2. Compute Gini index or Information Gain

- For each feature, calculate how well it separates the data into the target classes (diet types)

3. Based on selected feature Split the dataset into subsets based on the
selected feature

- Recursively apply the splitting process to each subset

4. *while*(∀*D* ∈ *DietType*)

Repeat steps 2-3

5. Assign a diet category (target) to each leaf node

- The leaf node will represent a specific diet recommendation (e.g., highprotein, balanced, low-carb)

4.3.2. PseudoCode- Clustering

1. Initialize K=3 clusters
- Randomly select K centroids (centers of clusters)
2. Repeat until convergence:
a. Assign each user (data point) to the nearest centroid
∀i compute distance
$d(p,q) = \sqrt{\sum_{i=1}^{n}(p_i - q_i)^2}$ b. Update centroids:
- For each cluster, compute the new centroid as the mean of the users assigned to that cluster
3. Stop if centroids do not change significantly (convergence reached)

4.4. Proposed Framework

The proposed integrated framework offers Machine Learning (ML) and Operations Research (OR) as a powerful tool to optimize balanced diets for gym enthusiasts. This framework influences the strengths of both domains to create a personalized and efficient diet optimization system. The paper

focuses the use of Machine learning techniques for predicting and analyzing the requirement of every one based on parameters like age, gender, weight, body type, training intensity, and fitness goals. By training a model on a large dataset of gym-goer profiles, food items, and their nutritional values, machine learning can uncover complex patterns and relationships between various types of attributes.
Paper proposes the use of Operations Research methods, specifically linear programming (LP) or integer programming (IP), for developing mathematical models to ensure the optimization of diet plans. These models would aim to minimize cost while satisfying constraints related to caloric intake, macro nutrient distribution , micronutrient requirements, and dietary preferences or restrictions. The goal is to find the best combination of food items that meets the gym enthusiast's specific nutritional needs, given their exercise regimen and goals.
Hence the proposed integration of ML and OR claims that the system will become flexible and can able to adapt individual preferences and customize the training schedules or fitness goals. For example, as the gym enthusiast progresses and their training intensity increases, the ML model can adjust the nutritional recommendations dynamically. Meanwhile, the OR optimization framework ensures that the meal plans remain cost-effective and nutritionally balanced. This integrated approach offers a robust solution for personalized, real-time diet optimization, making it easier for gym enthusiasts to meet their fitness goals in an efficient and sustainable manner.

5. Implementation

A python code has been implemented after a problem statement is derived from the given dataset.The approach includes clustering users based on their profiles and fitness goals and generating personalized diet plans using mathematical optimization. Libraries used for the development are sklearn for clustering ,scipy.optimize for linear programming ,pandas and numpy for data manipulation and matplotlib , seaborn for visualization.

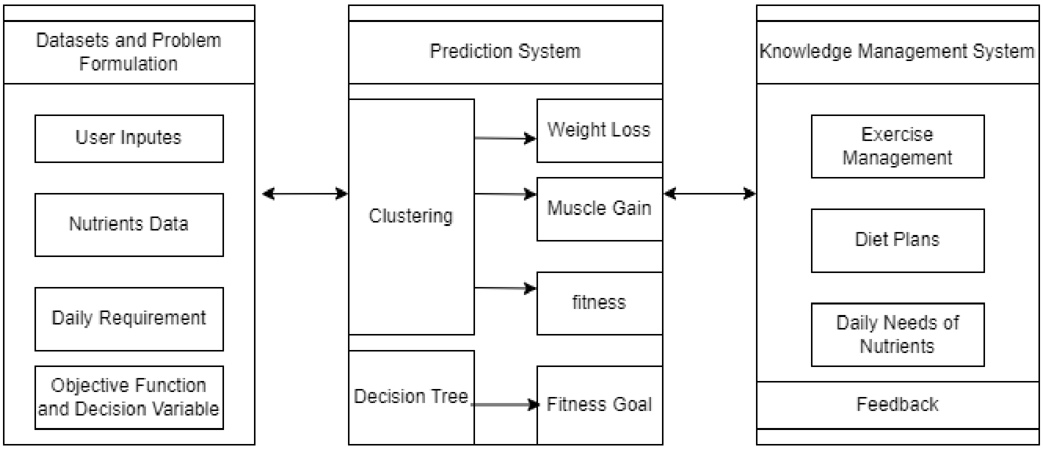

Figure 2: Proposed flow of Model

6. Results and Analysis

6.1. Relationship between complexity and accuracy

The Figure 3 tells information about various comparisons.

- Complexity increases logarithmically as the number of samples grows due to the dependency on $O(T \cdot N \cdot d \cdot \log N)$.
- This highlights the efficiency of Gradient Boosting for moderate sample sizes but shows its computational intensity for very large datasets. • Complexity grows quadratically with the number of decision variables $O(m \cdot n^2)$.
- For problems with a large number of variables, the computational cost may be a problem.
- Accuracy (R^2 score) is better if the number of samples increases shows the benefits of larger datasets in training.

6.2. complexity, runtime, and accuracy trends

Figure 4 shows following analysis : Complexity increases linearly with the number of features, as each additional feature increases the computations required for every tree in the ensemble. Highlights the need to carefully select

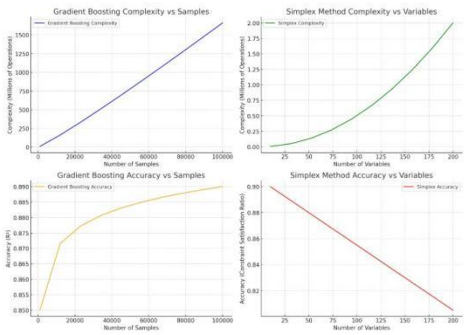

Figure 3: Relationship between complexity and accuracy of models

features to balance performance and computational cost. The normalized runtime demonstrates how Gradient Boosting scales with samples and how the Simplex method scales with the number of variables.Gradient Boosting has a logarithmic component, while Simplex grows quadratically with variables. Gradient Boosting shows improving accuracy with more samples. Simplex method accuracy decreases slightly as the number of variables grows, due to the increased challenge of satisfying constraints in higher dimensions. Figure 5 shows the clear analysis of all the three clusters including individual focus on calorie reduction and maintaining a balanced macro nutrient ratio for weight loss.Lower optimized cost suggests simpler or more cost-effective dietary needs, such as high-fiber and low-fat foods. Represents users aiming to maintain their current fitness level or weight.Moderate cost could reflect balanced nutrient intake with no extreme dietary restrictions. Focuses on individuals targeting muscle gain, requiring higher protein intake and potentially more expensive food options like lean meats and supplements.Higher optimized cost aligns with increased nutritional requirements. Figure 7 shows the progression of the objective function value as the Simplex Method iterates. The objective function value decreases steadily, demonstrating the efficiency of the Simplex algorithm. Convergence to the optimal solution is evident as the progression plateaus at the final iteration.

7. Conclusion

The integration of clustering and the Simplex Method provides a practical and efficient framework for optimizing balanced diets tailored to the distinct needs of gym enthusiasts. By clustering people into groups like Weight Loss,

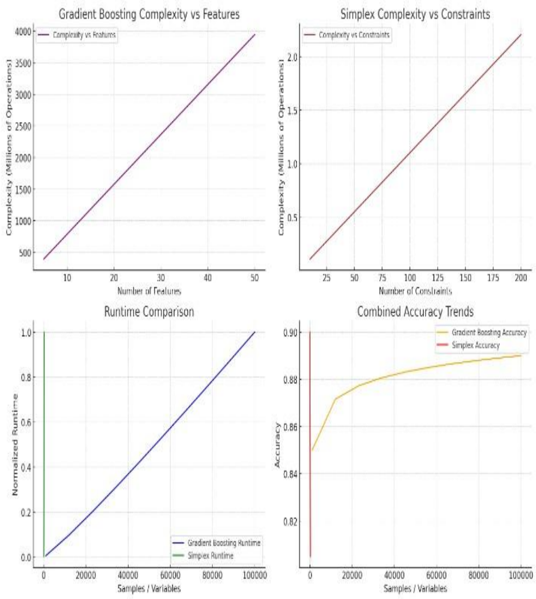

Figure 4: complexity, runtime, and accuracy trends

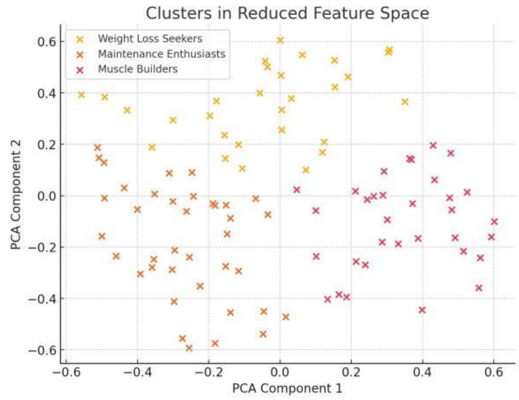

Figure 5: Clusters in reduced space

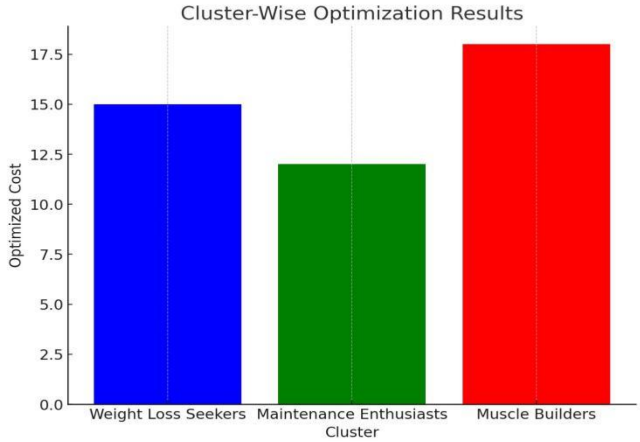

Figure 6: Clusterwise Optimization cost

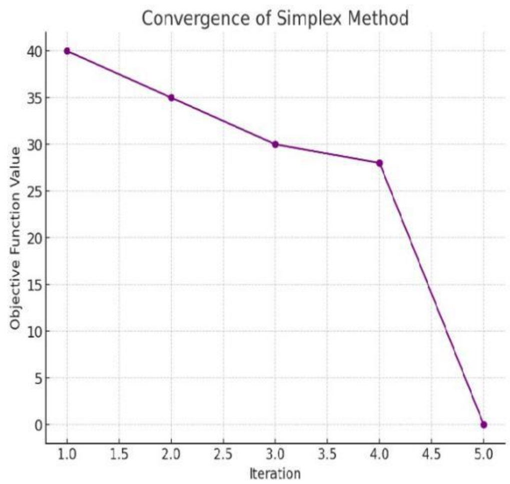

Figure 7: Convergence of Simplex Method

Muscle Builders etc clustering ensures personalized dietary planning based on specific fitness goals and nutritional requirements. The Simplex Method complements this by minimizing dietary costs while adhering to the constraints of each cluster, highlighting its effectiveness in handling complex optimization problems. This approach not only enhances personalization but also provides actionable insights into the cost implications of varying dietary needs. While the method is computationally efficient for moderate datasets, further refinement could address scalability for larger populations and incorporate dynamic adjustments based on user feedback. Overall, this framework bridges the gap between generic dietary advice and individualized nutrition planning, making it a valuable tool for fitness and health management applications. Appendix text.

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