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A Hybrid Machine Learning-Based Nutrition Recommendation System for Personalized Dietary Plans

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Abstract

In the modern health landscape, personalized nutrition is crucial for promoting wellbeing and managing chronic diseases. As we all move forward with our modern and technologically oriented lifestyle, the risk of suffering from various health ailments is very high. In this study, a hybrid system of nutrition recommendations, a combination of machine learning, data extraction, and visualization, is introduced to offer a personalized dietary solution. The system takes Body Mass Index (BMI), and incorporates medical history, food preferences, allergies and calorie consumption to produce custom meal plans. This platform increases the adherence to the diet, user-interaction, and wellbeing in the long term by providing an interactive graphical user interface and real-time data visualization.

Keywords: BMI, meal plans, calorie intake, allergies, nutrition recommendation system.

1 Introduction

The health-conscious trend has been growing for decades alongside the growing technology. Not only are people more aware of their health, but they have also merged their daily nourishment intake with AI. One area that specifically has attracted the applause of AI systems is in giving individualized dietary information [1]. As diseases like diabetes, hypertension, and food allergies become more common, the demand for customized dietary solutions grows. Through the application of machine learning, big data analysis, and predictive modeling, these AI-powered systems are capable of processing immense quantities of nutrition facts and user-based data in order to provide individualized diet advice. The personal factors are not traditionally the foundation of regular diet advice and therefore rely heavily on the recommendation models that are based on artificial intelligence. As technology in data-driven decision-making is evolving, automated dietary recommendation systems can offer

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individualized food recommendations depending on BMI, food requirements, and calorie intake of a user.

This algorithmic nutrition new recommendation algorithm, therefore, provides customized nutritional plans with regard to the individual, diet, health conditions, and lifestyle differences. The system will examine the data of users and suggest them appropriate meals based on their health condition. The system works with a structured index of food items with nutritional content and employs a filtering method to the user input such as height, weight, medical conditions such as medications, allergies, dietary restrictions, and needed caloric intake limits. Unlike previous nutrition programs which indicate their direction with generalized dietary guidelines, this program provides original user data in real-time and adjusts recommendations to its own purpose, such as muscle-building, weight management or chronic illness treatment. This system has a user interface that is interactive and proposes to them tailored meal plans to facilitate their healthy eating. To enhance nutrition awareness, Hybrid Nutrition Recommendation system integrates significant ideas of data processing, managing inputting, and providing decisions based on the data. The system can assist individuals in balancing their eating needs besides responding to any possible health risks through an effective algorithm that provides appropriate meal choices in the database. This research studies the structure, execution and efficiency of the system in providing an appropriate meal plan. The system also addresses the future of the intelligent nutrition recommendation systems and potential health sector applications.

2 Literature Survey

Personalized nutrition recommendation systems have gained a decent portion of praise in recent years since they have an opportunity to positively impact the dietary habits and health outcomes of the person. With a combination of machine learning (ML), artificial intelligence, and deep learning, a number of new opportunities have been opened to use in food recommendation systems.

2.1 Health Data Integration and Genetic Personalization

The authors in [2] explored the use of genetic markers and metabolic profiles to improve diet recommendations. Although their method gave promising results in personalizing nutrition, the research did not have any real-time input of data, data extraction, or data cleaning processes, which was one of its biggest limitations. The authors in [3] also explored genetic testing to modify diet recommendations for people with metabolic syndromes. But this work did not include a thorough dietary monitoring and machine learning for real-time adaptability, which could improve its performance.In [4], the authors studied long-term randomised controlled trials (RCTs) and concluded that high-protein diets did not have any apparent beneficial or deleterious effects on any of the markers of obesity, cardiovascular health, or glycemic control. Thus, the evidence on the effectiveness of high-protein diets in overweight and obese treatment is too informal to promote the implementation of high-protein diets in the diet of overweight and obese patients. In [5], it was observed that an imbalance in gut microbiota may play a role in the development and progression of chronic degenerative diseases. Regarding personalization, [6] explored tailored strategies for managing individuals with food allergies and suggested that such personalized approaches are becoming increasingly viable with advancements in diagnostic tools and understanding of allergic phenotypes.

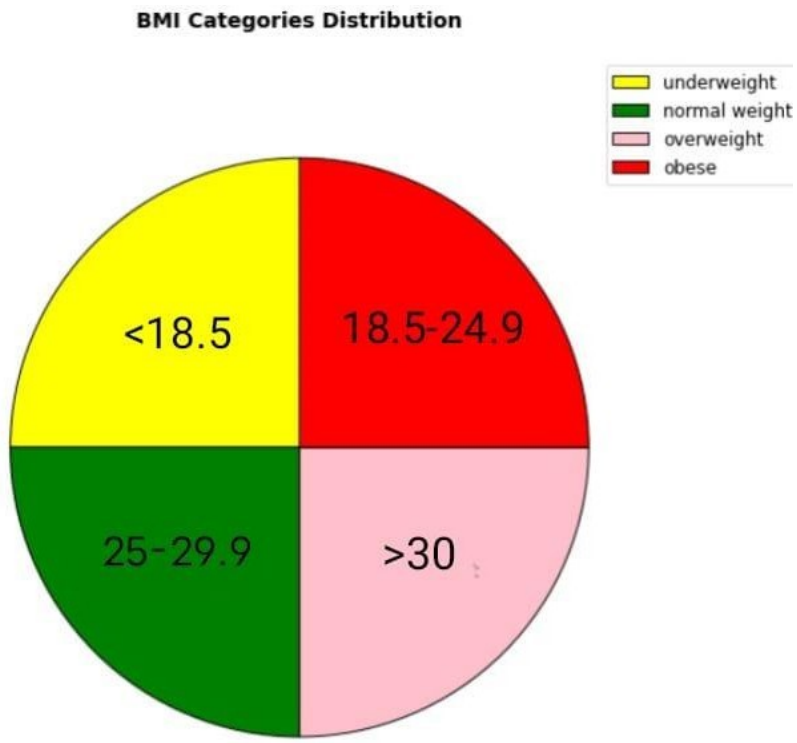


Fig. 1: Distribution of BMI categories

2.2 AI and Machine Learning in Dietary Recommendations

The authors in [7] worked on an AI-based program to provide users with better food preferences. Though it gave higher prediction accuracy, it did not have a simple graphical user interface (GUI) as well as visualization, which was a big disadvantage. Similarly, [8] presented the DIET RIGHT system based on Ant Colony Optimization (ACO), which gave diet plans using users' pathological information. Better scalability was provided by using cloud infrastructure, but since the ACO is a complicated model, the real-time performance was restricted. A hybrid food recommendation system that used K-Nearest Neighbors (KNN) and content filtering, presented by [9], helped to expand the diet recommendations. Their solution improved the accuracy and flexibility, but the system was challenged by higher processing overhead and synchronization issues because of the complicated recommendation pipeline. In [10], the authors urged practitioners to critically review existing protein intake guidelines and accountable presentation and use of the RDA as a minimal protein requirement and not as a requirement that is established to fulfill the population in an optimal manner. According to authors in [11], if NRS had been designed adequately, implemented and eventually assessed it could have served as a useful tool to enhance nutrition and healthy lifestyle.

2.3 Allergen Detection and Multi-User Meal Planning

The research on allergen and sensitivity identification combined allergen avoidance in nutrition advice to improve tailored nutrition for people with food restrictions. But the system did not consider the fitness objectives, family meal planning, or machine learning flexibility. The second research concentrated on the meal planning for families and groups having different nutritional needs. Although it tackled an important issue, the system was not flexible enough to manage the complicated health issues and did not use machine learning for improved personalization. In [12], the authors focused on the nutritional management of IgE-mediated food allergy and other aspects of the avoidance diet.

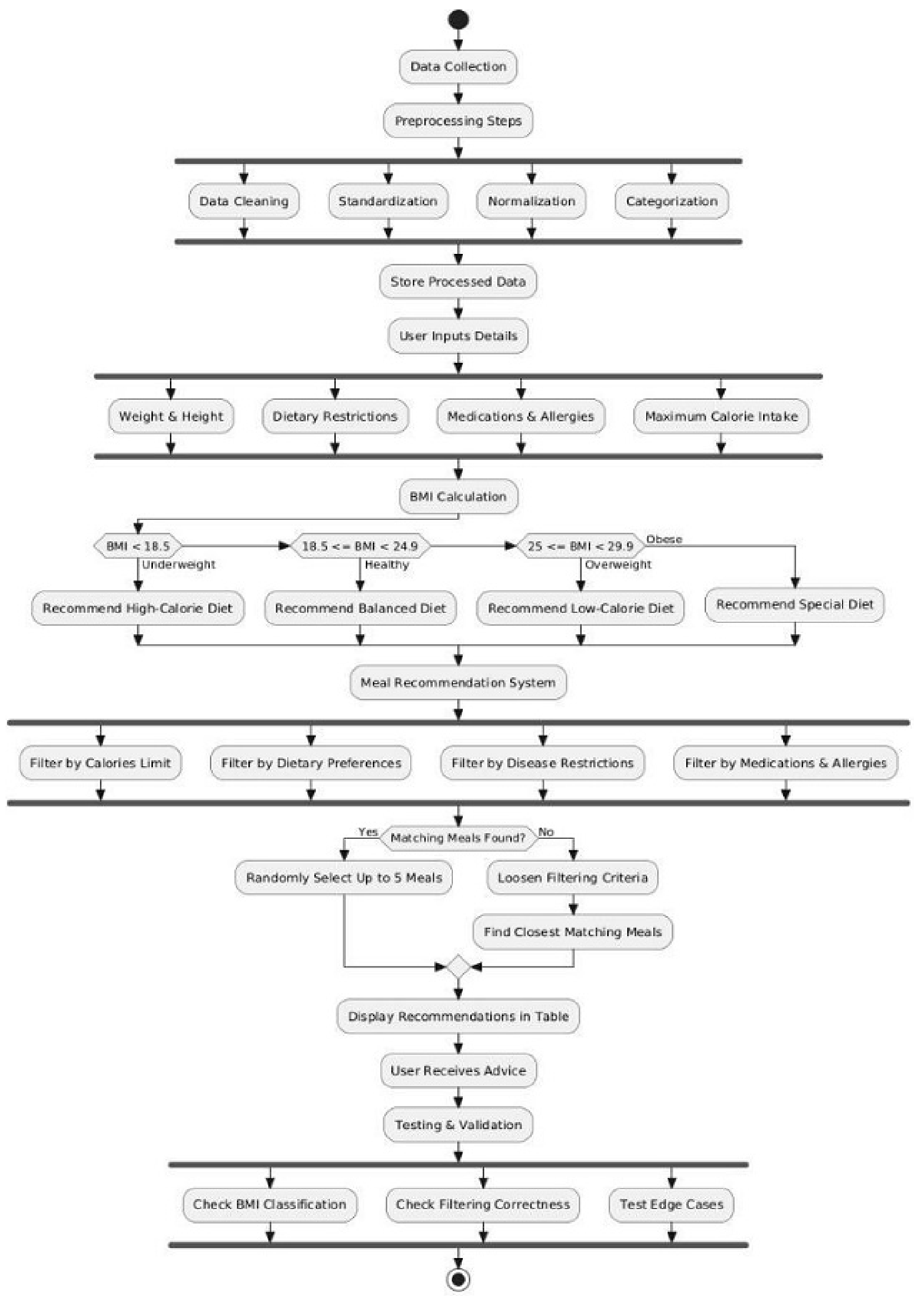


Fig. 2: Process Flow

2.4 User Engagement and Long-Term Compliance

A user engagement and interface design study the significance of in-built UI/UX and real-time feedback in nutrition apps. It was associated with fitness tracking and not with management of chronic health conditions. The authors in [13] debated the collaboration between diet and fitness, focusing on macronutrient customization for fitness purposes. However, medical conditions were not factored in by the study, hence its limited usefulness for people with chronic diseases. In another study on long-term dietary adherence, the efficacy of personalized diet plans in optimizing adherence in patients with chronic diseases was examined. Although the study reported on adherence patterns, it did not highlight the importance of a user-friendly interface to facilitate interaction. In [14], the authors described the application of interventions that enhance the interaction with DHIs aimed to achieve such health outcomes; the actual influence has not been determined due to the low level of evidence. The authors in [15] recommended group-based nutrition education using BCT and also proved to be the most promising in the improvement of healthy eating in older adults living in communities. The studies that were reviewed exhibit an increasing concern with incorporating health information, AI, and user engagement mechanisms into dietary advice systems. Nevertheless, there are various limitations that remain, such as the absence of real-time adjustment, machine learning-based personalization, and easy-to-use interfaces. Future research needs to bridge these gaps through the creation of systems that embrace dynamic monitoring, smooth data merging, and greater user engagement in order to enhance dietary compliance and health outcomes.

3 Proposed Methodology

This research is based on the intended course of action in creating a hybrid nutrition recommendation system that provides customized meal recommendations according to the health limitations of the user. The main steps of the methodology are

3.1 Data Collection and preprocessing

- Data Collection: The system applies structured data, which involves various foods, depending on various features. Some are categories of diets, such as vegetarian and vegan, as well as non-vegetarian food, and macronutrient content, e.g., the level of calories. Other medical characteristics such as disease-specific diets, dietary restrictions, potential medical interactions, and allergens are also considered in the data set.
- Data processing: Preprocessing needs to be done before studying the data to make sure that our data is accurate and consistent. Firstly, the data is cleaned by removing redundant data, filling the missing values, and correcting discrepancies. Then, standardization is carried out. Here, the text fields, for example, in diet categories, allergens, and diseases, duplicate spaces are removed. After which normalization is done, checking nutrient values for outliers and correcting them if needed. Categorization is then done where food items are labeled according to the match with various health conditions, which improves the filtering efficiency. Data Preprocessing ensures that the dataset used is consistent and planned and gives tailored, personalized recommendations.

3.2 BMI calculator

We use the following standard formula to calculate the BMI index of any individual:

$$\text{BMI} = \frac{\text{Weight (kg)}}{\text{Height (m)}^2}$$

The following is the BMI classification:

- $$BMI < 18.5 : Underweight$$
- $$18.5 < BMI < 24.9 : HealthyWeight$$
- $$25 < BMI < 29.9 : Overweight$$
- $$BMI\,30 : Obese$$

The distribution of BMI categories is shown in figure 1 This classification of BMI helps the diet recommendation system to find the users' health status.

3.3 Meal Recommendation System

The system uses a rule-based filtering technique to suggest suitable meals. The process of filtering involves the following steps:

- User Input Collection : The user inputs information such as weight, height, dietary restrictions, medications, allergies, and maximum calorie intake.
- Data Filtering: The filtering procedure starts with the calorie limit, in which meals that exceed the user's allocated calorie limit are excluded. Secondly, dietary preferences are applied where only meals with the same diet category as that selected by the user, e.g. vegetarian or vegan, are left. The system then implements disease-specific exclusions, in which meals that contain the ingredients that are off-limits for the patients with medical conditions such as diabetes are excluded. Finally, medication and allergy considerations are addressed by excluding foods that contain allergens or ingredients that may contraindicate prescribed medications.
- Recommendation Selection : If appropriate meals are present, the system selects randomly up to five suggestions. But if there are no direct matches, it modifies filtering parameters and provides the nearest available meals with matching calorie levels.

3.4 User interaction and system implementation

The system is implemented as a command line interface (CLI) where users are able to compute their BMI and get personalized dietary recommendations. The recommendations are presented in tabular form using the Tabulate library for better readability.

3.5 Testing and Validation

The system is tested using different test cases to verify accuracy and reliability. It is tested with different BMI values to check correct classification. Moreover, different dietary and medical inputs are tested to ensure the efficiency of the filtering process. For testing the robustness of the system, edge cases are tested, e.g., users with more than one dietary restriction, to ensure it performs well in complicated situations. This approach defines a concise, systematic methodology through which the system operates, performing data processing and making tailored nutrition recommendations. The complete process flow is shown in figure 2.

4 Results and Discussion

The hybrid nutrition recommendation system that was created in this research is founded on the evidence-based wisdom that suggests tailored meal recommendations to the users, depending on multiple inputs such as weight, height, BMI, food constraints, allergies, medications, and diseases. The system combines a CSV database of meal recommendations, nutrition data, and medical-related data to produce meal plans that are tailored.

A two-level filtering mechanism is utilized in the system to make it more flexible. The system first scans through the meal options that exactly fit the specifications given by the user. The system will compensate by offering approximated suggestions in the event of an occurrence of no exact matches. They are cleverly sorted by the key factors, such as calorie content, such that given very specific and restricted nutritional requirements, the users can still find useful suggestions. This is an adaptive strategy whereby the users are always facilitated regardless of the complexity of their needs. The same is depicted in the output of figure 3 and figure 4.

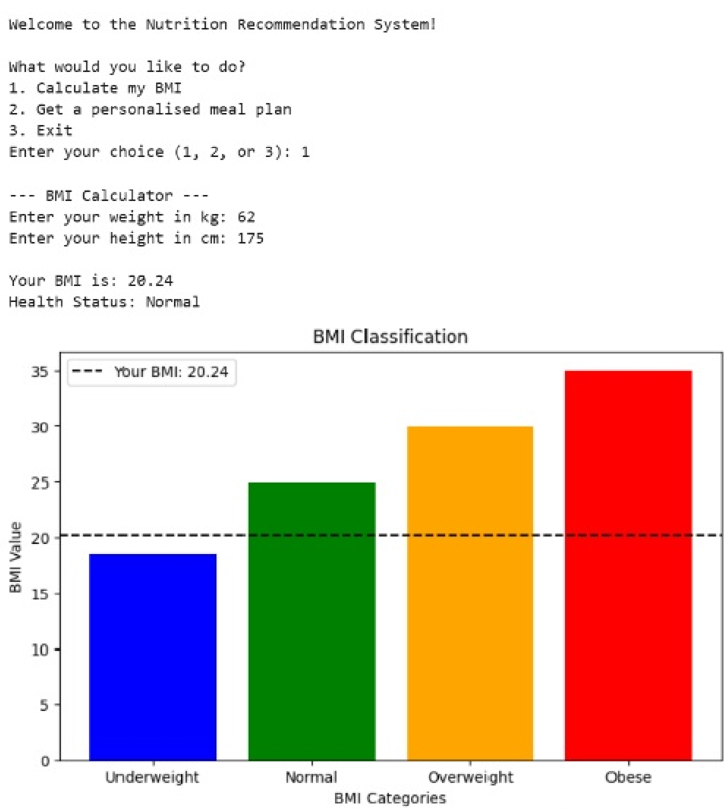
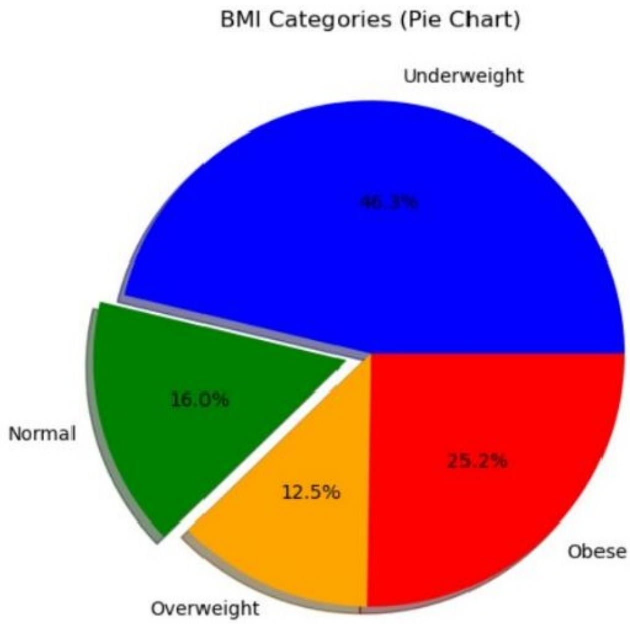


Fig. 3: Generation of personalised recommendations- Initial steps




```
What would you like to do?
1. Calculate my BMI
2. Get a personalised meal plan
3. Exit
Enter your choice (1, 2, or 3): 2

--- Personalised Meal Plan ---
Enter your weight in kg: 62
Enter your height in cm: 175
Enter any diseases (comma-separated): Diabetes
Enter any medications (comma-separated): Atorvastatin
Enter any allergies (comma-separated): Pollen
Enter your dietary restrictions (e.g., Vegetarian, Vegan, Non Vegetarian): Non Vegetarian
Enter your maximum calories intake: 3000

Here are your personalized food recommendations:
+--------------------------------------------------------------------+----------+---------+--------+-------+
|                        Food Recommendations                        | Calories | Protein | Carbs  | Fats  |
+--------------------------------------------------------------------+----------+---------+--------+-------+
|               Beef Burgers, Sweet Potato Fries, Coleslaw           |   2923   |  136.6  | 370.86 | 55.17 |
|            Shrimp Stir Fry, Jasmine Rice, Steamed Vegetables       |   2357   | 133.84  | 394.45 | 85.37 |
|               Beef Steak, Mashed Potatoes, Green Beans             |   2539   |  97.01  | 346.21 | 64.34 |
|                    BBQ Ribs, Coleslaw, Cornbread                   |   2307   |  72.22  | 267.0  | 45.9  |
| Grilled Chicken Salad, Salmon with Steamed Vegetables, Whole Grain Pasta |   2367   |  69.03  | 396.31 | 95.62 |
+--------------------------------------------------------------------+----------+---------+--------+-------+

What would you like to do?
1. Calculate my BMI
2. Get a personalised meal plan
3. Exit
Enter your choice (1, 2, or 3): 3
Thank you for using the Nutrition Recommendation System. Goodbye!
```

Fig. 4: Generation of personalised recommendations – Final steps

5 Conclusion and Future Scope

The system can potentially help individuals manage their eating habits, especially those with certain medical conditions or dietary restrictions. It can be a starting point in encouraging healthier lifestyles and preventing diet-related diseases. Although the existing system has a strong basis, there are some areas of future research and development aimed at improving its functionality, including extraction of data from wearable devices and development of a user-friendly mobile or web application.

Declarations

- The authors received no specific funding for this study.
- The authors declare that they have no conflicts of interest to report regarding the present study.
- No Human subject or animals are involved in the research.
- All authors have mutually consented to participate.
- All the authors have consented the Journal to publish this paper.
- Authors declare that all the data being used in the design and production cum layout of the manuscript is declared in the manuscript.

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