Optimizing Nutrition: A Cost-Effective Meal Generator System

CS221 Project Proposal — Nuria Perez Casas

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Problem Statement and Task Definition

Have you ever found it challenging to plan your meals for the week? Maybe life got too busy, and you ended up relying on fast food again. Or perhaps you felt like you were constantly overspending at the grocery store? I can relate. My goal for this project is to develop a system that recommends weekly recipe menus optimized for low cost and nutritional health. The system will offer recipes that strike a balance between affordability and healthy eating. It will adhere to the user's budget and provide a shopping list to ensure nothing is forgotten during grocery shopping.

Input/Output Behavior

The system will utilize a comprehensive dataset compiled from various online sources, containing the following information:

- **Recipes**: Names, ingredient lists, descriptions, preparation instructions, and serving sizes.
- **Ingredients**: Individual costs, nutritional information (calories, macronutrients, vitamins, and minerals), and complexity ratings.
- **Health Scores**: Calculated based on the nutritional content of each recipe, considering balance and essential dietary components.

User Inputs:

1. **Budget**: The total amount the user is willing to spend on groceries for the week (in dollars).
2. **Servings**: he number of servings needed (e.g., 2 to 4).
3. **Recipes Needed**: The total number of recipes desired for the week (e.g., 5).

Expected Outputs: A list of recommended recipes within the user-defined budget, including: Recipe names, Estimated total costs, Ingredient lists (with quantities), Preparation instructions, Nutritional summaries (e.g., total calories, macronutrient breakdown)
The system will also provide an organized shopping list consolidating all required ingredients to streamline the grocery shopping experience.

An Evaluation Metric

To evaluate the algorithm's performance, we will focus on cost efficiency by measuring the average cost per selected recipe relative to their overall health scores. We will assess how effectively the system optimizes for low-cost recipes while meeting nutritional standards. An analysis of the health scores, including computing the average health score of the selected recipes over a week, will be part of this evaluation. Additionally, we may conduct a trade-off analysis to observe how changes in weighting affect recipe selection (e.g., determining if we are sacrificing health for cost savings).

Related Works

Balintfy [1] discusses early meal planning algorithms. Nakandala and Lau [2] analyze cost-effective nutritional strategies. Wallingford and Masters [5] explore modern approaches to meal planning. Stern [4] offers insights into dietary preferences and constraints. Furthermore, the work by [3] contributes to recipe optimization methodologies.

Baseline and Oracle

In my project, the baseline assigns a random score to each recipe without considering health factors for a balanced diet. The total cost is computed by summing the static ingredient costs based on the number of servings. The only constraints include ensuring no recipe repeats and staying within the user's budget. This baseline approach does not emphasize balancing health and cost; instead, recipes are randomly selected as long as they meet the budget criteria.
In contrast, the oracle focuses on minimizing cost while maximizing health scores. It avoids recipe repetition and ensures that all selections stay within budget. If time permits, I may introduce additional constraints to limit ingredient repetition, particularly for key items like the main protein source, which could recur unintentionally despite a high health score; for example, I wouldn't want to eat chicken every day. The oracle represents the optimal balance between cost and health score, showcasing the best possible outcome for this problem.

Methodology

To create my meal generator system, I will employ a structured approach that balances cost and health in recipe selection.
First, I will calculate the total cost of each recipe by summing the costs of all its ingredients based on average prices. For example, if a recipe requires 1 lb of chicken at \$3.50 and 0.5 lb of rice at \$1, the calculation would be: Cost of Recipe = $(1 \times 3.50) + (0.5 \times 1) = \$4.00$. This step is crucial for ensuring that every recipe aligns with the user-defined budget, establishing a solid foundation for the entire system.
Next, I will assign a health score to each recipe by evaluating its nutritional content, taking into account macronutrient balance, caloric density, and essential vitamins and minerals. I will use a weighted formula to compute this health metric, incorporating both macronutrient ratios and calorie information. The following phase will involve multi-objective optimization, where I will employ a weighted sum formula to combine the health score with the inverse of the recipe cost, yielding an overall score. By adjusting the weights—w1 for health and w2 for cost—I can tailor the system to prioritize what the user values most, whether that's nutrition or affordability. Ultimately, I will rank the recipes based on this overall score and generate a weekly menu from the top selections that stay within budget, all while ensuring variety and avoiding repeated dishes.

Challenges

One of the primary challenges will be effectively balancing cost and health in recipe selection. For example, recipes featuring quinoa and salmon may be more nutritious but can significantly increase the overall cost. Conversely, options like pasta and canned vegetables might be more budget-friendly but could compromise nutritional value. This tension will require careful tuning of weights to ensure an optimal user experience.
Additionally, ensuring that the system can accurately fetch real-time prices and nutritional data from APIs poses a challenge. Keeping the ingredient price list updated will be crucial, and I may need to implement a caching mechanism to store previously fetched prices and nutritional values temporarily.
Another hurdle will be addressing user preferences and dietary restrictions. I will aim to implement a feedback loop allowing users to input dietary needs (e.g., gluten-free, vegetarian) while also providing an option for them to suggest new recipes. This flexibility will require additional considerations in the algorithm to adapt to varying user needs.

References

[1] Joseph L. Balintfy. A mathematical programming system for food management applications. *Interfaces*, 6(1):13–31, Nov. 1975.

[2] Dilupa Nakandala and Henry C. W. Lau. An application of a fuzzy-based optimisation model for selecting food products based on cost and nutrition. *Journal of Research for Consumers*, (24):88–106, Jan. 2014.

[3] Adrian Jenssen L. Pe, Jerahmeel Kua Coching, Seth Gabriel D. Yeung, Wynnezel Akeboshi, and Robert Kerwin C. Billones. Cost optimization for weekly meal planning of college students based on calorie constraints using linear programming (lp) method. In *2022 IEEE 14th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM)*, pages 1–6, 2022.

[4] AL Stern, S Levine, SA Richardson, NT Blackstone, C Economos, and TS Griffin. Improving school lunch menus with multi-objective optimisation: nutrition, cost, consumption and environmental impacts. *Public Health Nutrition*, 26(8):1715–1727, 2023.

[5] Jessica K. Wallingford and William A. Masters. Least-cost diets to teach optimization and consumer behavior, with applications to health equity, poverty measurement and international development. *arXiv preprint arXiv:2312.11767*, 2023.