Mathematical Model Formulation for Diet Optimization Using Genetic Algorithm

1. Problem Description

The goal is to optimize the composition of a daily diet by selecting appropriate quantities of various food items. The model ensures that an individual's nutritional requirements are met while minimizing the total cost or maximizing the overall health value of the selected items. The problem is formulated as a constrained optimization task suitable for solving using Genetic Algorithms (GA).

2. Decision Variables

Let x_i denote the quantity (in grams) of food item i included in the daily diet, where i = 1, 2, ..., n and n is the total number of available food items.

3. Objective Function

Two possible objective functions can be considered:

- a. Minimize the total cost of the diet:

  Minimize $Z = \Sigma (c_i * x_i)$, where c_i is the cost per gram of food item i.

- b. Maximize a nutritional health score:

  Maximize $Z = \Sigma (h_i * x_i)$, where h_i is the health score per gram of food item i.

4. Constraints

Note: The model uses symbolic values such as C_min, P_max, etc. These values represent daily nutritional targets and should be determined based on user-specific needs, such as age, gender, activity level, or dietary goals. The implementation should allow users to input or select these values dynamically.

Age Range Gender Activity Level Calories/day Protein/day (g)

Age Range	Gender	Activity Level	Calories/day	Protein/day (g)
19–30	Male	Sedentary	2400	56
19–30	Male	Moderate	2600	56
19–30	Male	Active	2800	56
19–30	Female	Sedentary	2000	46
19–30	Female	Moderate	2200	46
19–30	Female	Active	2400	46
31–50	Male	Sedentary	2200	56
31–50	Male	Moderate	2400	56
31–50	Male	Active	2600	56
31–50	Female	Sedentary	1800	46
31–50	Female	Moderate	2000	46
31–50	Female	Active	2200	46

The optimization is subject to the following constraints:

- a. Caloric Constraint:

  $C\_min \leq \Sigma (cal_i * x_i) \leq C\_max$

- b. Macronutrient Constraints:

  $P\_min \leq \Sigma (protein_i * x_i) \leq P\_max$

  $F\_min \leq \Sigma (fat_i * x_i) \leq F\_max$

  $CHO\_min \leq \Sigma (carb_i * x_i) \leq CHO\_max$

- c. Micronutrient Constraints:

  $\Sigma (vitaminA_i * x_i) \geq V\_A\_min$

  $\Sigma (iron_i * x_i) \geq Fe\_min$

(and other required micronutrients)

- d. Quantity Bounds:

  $0 \leq x_i \leq U_i$, where U_i is the upper bound for food item i.

- e. Optional Constraints:

  - Food diversity (at least one item from each major group)

  - Cultural or dietary exclusions (e.g., limit on processed foods)

5. Genetic Algorithm Approach

The problem is solved using a Genetic Algorithm (GA) where each chromosome represents a vector of food quantities. The GA uses fitness evaluation based on the chosen objective (cost or health score) combined with penalties for constraint violations. Operators such as selection, crossover, and mutation are adapted to handle real-valued decision variables.