A Genetic Algorithm Approach to Optimize Planning of Food Fortification

2011 Joint Statistical Meetings

Dave Osthus

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Outline

1. Nutrition Background
2. Food Fortification Background
3. Optimal Fortification Planning Approach
4. Genetic Algorithms
5. Results via an Example
Usual Daily Nutrient Intake

- **Usual Daily Nutrient Intake**: The long run average of daily nutrient consumption.

- Reliable estimation of usual daily nutrient intake distributions has been thoroughly explored (National Research Council, 1986; Nusser et al., 1996)

- Usual daily nutrient intake distributions are used to:
  1. Identify populations with nutrient inadequacies.
  2. Develop programs to combat these inadequacies.
Identification of Nutrient Inadequacies

- **Prevalence of nutrient inadequacy** \( (\alpha_{PoI} \in [0, 1]) \): Estimated as the proportion of individuals in a population with usual daily nutrient consumption **below** the Estimated Average Requirement (EAR).
  - **EAR**: Daily nutrient intake level that is estimated to meet the needs of half the healthy individuals in a specified age and gender population.

- **Prevalence of nutrient excess** \( (\alpha_{PoE} \in [0, 1]) \): Estimated as the proportion of individuals in a population with usual daily nutrient consumption **above** the Tolerable Upper Limit (UL).
  - **UL**: Highest level of nutrient consumption regarded as safe for individuals in a specified age and gender population.
Development of Programs to Combat Nutrient Inadequacies

- Prevalence of nutrient inadequacy and/or excess goals are set ($\beta_{PoI} \in [0, 1]$ and $\beta_{PoE} \in [0, 1]$, respectively).
- **Food Fortification Plan**: An intervention where specific amounts of nutrient are added to specific food vehicles.
  - Candidate food vehicles and fortification limits are selected and set by food scientist.
- In practice, if the fortification plan results in $\alpha_{PoI} \approx \beta_{PoI}$ and/or $\alpha_{PoE} \approx \beta_{PoE}$ and the cost is reasonable, then the plan is considered successful.
- **Main Question**: How do we identify the “best” fortification plan?
  - “Best” plan is the fortification plan that meets the prevalence of inadequacy/excess goals for minimal cost.
Optimization Function

Notation

- $\gamma_k$: Additional amount of nutrient added to one unit of food vehicle $k$, $k \in \{1, 2, \ldots, K\}$ and $\gamma_k \in [0, \text{fortification limit for food vehicle } k]$. 
- $c_k$: Cost to add one unit of nutrient to one unit of food vehicle $k$, $c_k \geq 0$. 
- $\lambda$: A large number (e.g. 1,000,000). A penalty for selecting a plan that does not meet the prevalence of inadequacy/excess goals.

Optimization Function

$$f(\gamma_1, \gamma_2, \ldots, \gamma_K) = \sum_{k=1}^{K} (c_k \ast \gamma_k) + \lambda[|\alpha_{PoI} - \beta_{PoI}| + |\alpha_{PoE} - \beta_{PoE}|]$$

Note

$$\frac{\partial f}{\partial \gamma_k}(\gamma_1, \gamma_2, \ldots, \gamma_K)$$ is not analytically tractable. Numerical optimization method utilized.
A genetic algorithm is a stochastic optimization algorithm that attempts to mimic the evolutionary process as demonstrated in nature by biological individuals.

- Few restrictions.
- Results get better as run time increases.
Data: Ugandan children between 6 and 24 months of age.

- **Nutrient:** Vitamin A
- **Food Vehicles:** Sugar, Vegetable Oil, Wheat Flour and Maize Flour
- **Pre-fortification:** $\alpha_{PoI} = 0.93$ and $\alpha_{PoE} = 0.00$
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Questions?

(dosthus@iastate.edu)