

# The Menu Planning Problem: a Multiobjective Approach for Brazilian Schools Context

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## ABSTRACT

In this work, we developed a genetic algorithm for solving the automatic menu planning for the Brazilian school context. Our objectives are to create menus that: (i) minimize the total cost and, simultaneously, (ii) minimize the nutritional error according to the Brazilian reference. Those menus also satisfy requirements of the Brazilian government, for example: (i) student age group, (ii) school category, (iii) school duration time, (iv) school location, (v) variety of preparations, (vi) harmony of preparations and, (vii) maximum amount to be paid for each meal. To tackle this problem, we transformed our multiobjective in a mono-objective problem using the linear scalarization method and solved it with a genetic algorithm. We also developed a multiobjective algorithm based on the Non-dominated Sorting Genetic Algorithm (NSGA-II). Our results demonstrate that the multiobjective approach is 5 times faster, with 30 times more non-dominated solutions and give solutions that are statistically better compared with the mono-objective algorithm. Another advantage of this the approach is the diversity of solutions, allowing the professional (nutritionist) choose one among the various menus obtained by the algorithm, giving priority to the objective that is considered to be the most relevant in a given situation.

## CCS CONCEPTS

•Applied computing → Health care information systems; •Computing methodologies → Heuristic function construction; Optimization algorithms;

## KEYWORDS

Menu Planning, Genetic Algorithm, Evolutionary Computation, Combinatorial Optimization.

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## 1 INTRODUCTION

The eating plays a fundamental role during the life cycle of an individual, being responsible for his/her vital functions. Keeping that in mind, the Brazilian government created in 1955 the Brazilian School Feeding Programme (PNAE - *Programa Nacional de Alimentação Escolar*) with the goal of contributing to the growth, development, learning and school performance of students and the development of healthy eating habits through the provision of school meals and actions on nutritional education [1].

Only to demonstrate the combinatorial nature of the problem, suppose a menu planning composed of three meals (breakfast, lunch, and snack) for five days and a database having 111 culinary preparations divided in: rice(9) and beans(6); entree (24); side dish (20); main dish (12); dessert: fruits (11) and others (5); drink: juice (9) and others (5); bread/other cereal (10). There are about  $7.8 \times 10^{67}$  possible menu combinations.

The proposed approach presented in this work considers two fundamental aspects: reduce the cost of a menu and, simultaneously, meet the daily nutritional needs of the students. Desirable properties as variety, color, consistency of culinary preparation, financial cost limit and nutritional error are used as hard constraints. The MPP is modeled as a multiobjective problem using two conflicting objectives: (i) minimize the cost of the menu and, (ii) minimize the nutritional error following the guidelines published by the Brazilian reference [1].

## 2 PROBLEM DEFINITION

Although the menu planning problem has a combinatorial nature, it is not modeled as such, because the variables are continuous. The problem is classified as bi-objective minimization problem, and its mathematical formulation is given by:

$$\begin{array}{ll} \text{Minimize} & \text{Error Nutritional} \\ \text{Minimize} & \text{Cost} \\ \text{s.a:} & \left\{ \begin{array}{l} \text{Color Constraint} \\ \text{Consistency Constraint} \\ \text{Variety Constraint} \\ \text{Cost Limit Constraint} \\ \text{Nutritional Error Limit Constraint} \end{array} \right. \end{array} \quad (1)$$

Figure 1 represents a problem solution representing a menu. Each menu is defined for some days and for each day we have meals that are composed by preparations.

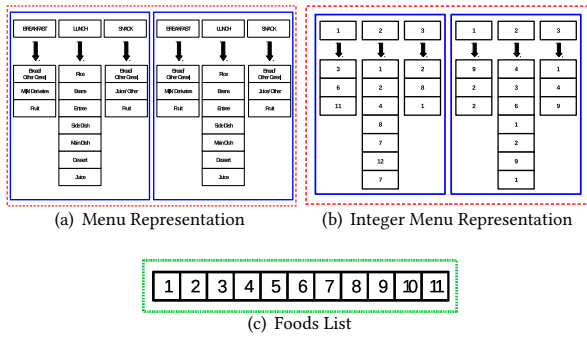


Figure 1: Representation of a two days menu

### 3 RESULTS AND DISCUSSIONS

The menu planning problem is characterized as a bi-objective problem, and it is dealt with two different methodologies. A priori, the problem is transformed into a mono-objective problem through scalarization methods. The scalarization method applied is the Linear Scalarization of the objectives and Genetic Algorithms are used to perform the experiments. Subsequently, we use the NSGA-II to solve the problem in a multiobjective approach. In both approaches, the constraints are handling via a penalization approach.

The genetic operators have the following characteristics: a tournament selection in which two random individuals are chosen and the one with the best function value is selected; the mutation chooses on a random day of the menu, and for each meal of this specific day, chooses randomly a preparation to be changed by another one of the same types; the crossover is performed within each type of meal. Considering the crossover between breakfast and snack, the cutoff point ranges from one to three and, between breakfast and lunch, between one to seven. Thus new individuals are generated preserving the genetic inheritance of its parents.

The parameters for both algorithms are: 100 individuals in the population, 1000 iterations, crossover rate equal to 0.8, mutation rate equal to 0.05, three meals daily in 5 days on the week. The limit values of the meals are fixed at: breakfast: R\$ 2,00, lunch: R\$ 4,00 and snack: R\$ 2,00. The age group considered was 4 to 5 years, equivalent to the full-time pre-school. The two algorithms were executed 30 times.

The performance assessment of both method can be done through the hypervolume indicator. Since we want to maximize the hypervolume value and there is no overlapping between both boxes, it is possible to say that the obtained hypervolume values of NSGA-II is significantly better than the ones obtained for the mono-objective GA. The randomization test [2] is also applied to the data. Figure 2 shows the boxplot of the obtained hypervolume for the two approaches.

The randomization result is described by the gray histograms presented in Figure 3, while the observed result is depicted as a filled black circle over the same figure. The statistical tests have been performed using mean(Mono-objective GA)-mean(NSGA-II) and, therefore, negative differences (situated on the left-side of the histogram) favor NSGA-II over mono-objective GA.

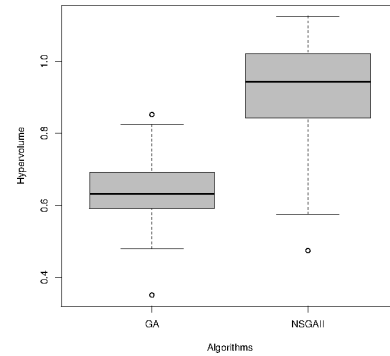


Figure 2: Boxplot of the samples of the hypervolumes generated for the algorithms.

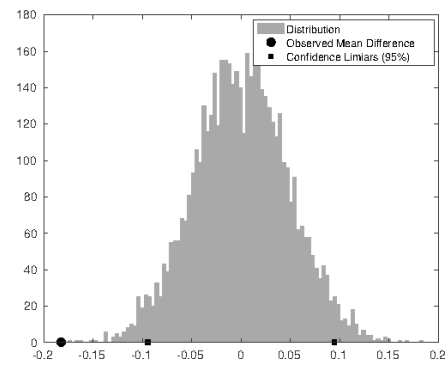


Figure 3: Randomization testing using the hypervolume. The result is statistically significant since the filled black circle lies on the left-hand side of the histogram.

### 4 CONCLUSIONS

This work deals with in the problem of weekly menu planning for Brazilian schools. The objective functions of the problem were: the nutritional error and the cost.

For solving the problem, two approaches were used in this work: a mono-objective, in which the problem was transformed into a mono-objective one using the weighted-sum approach and, then, a GA was used to solve it, and a multiobjective approach, in which a multiobjective GA, the NSGA-II, was directly applied to solve the problem. Results showed GA and NSGA-II can find feasible solutions for the problem however, using the hypervolume as a merit function, NSGA-II presented better solutions when compared to the mono-objective GA. In all cases, the proposed objectives were achieved and the constraints established by the government were met. The computational time for planning each menu was up to three minutes while the task would have been done in hours.

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