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A Decision-Making Technique for Financial Grant Allocation to Research Projects

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Abstract. The importance of financial support to scientific research is increasing due to international competition. Consequently, National, State and institutional foundations that provide financial grant to research projects face the responsibility of selecting projects efficiently. Hence, this paper proposes a technique to support the decision-making process of grant allocation to research projects. The selection process aims maximizing the overall cost-benefit relation. The data used in this study were from financial grant bids of the Research Foundation of the State of Tocantins – FAPT, in Brazil. The selection problem in question is a variation of the classic combinatorial optimization problem, which can be solved by the Tabu Search algorithm. Results have showed that this optimization technique provides a quick and accurate support to the selection process considering cost-effective criteria.

Keywords: Business intelligence, cost management, decision support, grant allocation, Tabu Search.

1. Introduction

The Selection Problem of Research Projects (SPRP) consists of the selection of the proposals of scientific that will receive financial support, that is, from the perspective of the Organization that sponsors the research it means to select a group of projects that should maximize the overall cost-benefit. Specifically, in order to deal with real data, this study uses data gathered from financial support bids of scientific research projects of the Research Foundation of the State of Tocantins – FAPT, in Brazil. The technique employed for optimization purposes was the Tabu Search [1], which presents consistent results for the classic combinatorial optimization problem.

Usually, a bid for granting financial support to scientific research projects has a total value limit, where each grant is limited to a certain amount and their sum should not exceed the total value limit. Hence, the SPRP problem is a variation of the problem of multidimensional knapsack, where there may be more than one constraint. The knapsack problem is a NP-hard problem [2], which means it does not have an algorithm to solve it in polynomial time. In accordance with [3], the knapsack problem comprises of n items to be placed in a backpack, which has capacity c. Each item j has associated a value p and a weight w. The backpack has to be filled getting the highest possible value without exceeding the capacity c. Generally, the issue is to determine which objects should be placed in the bag to maximize the total benefit such that the weight thereof does not exceed its capacity. The problem of knapsack is found in various segments of the industry [4], and other practical real-world applications. In this sense, the selection of an item from the bag is equivalent to choosing a project in SPRP, the weight of the item is equivalent to the value of the project and the value of the item is equivalent to the benefits of the project.

The SPRP can be solved by means of the Tabu Search algorithm (TS). TS is a successful heuristic method applied in various combinatorial optimization problems, which is a local search method that explores

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the space solution moving from one solution to another looking for its best neighbor and it never accepts movements to solutions already visited, because they are stored in a Tabu list [5].

The SPRP problem may also be considered similar to the decision-making for product portfolios such as for pharmaceutical research [6]. Another approach for project portfolio optimization problems was presented by Yang *et a.* [7], which is based on stochastic multi-criteria acceptability analysis. Additionally, another similar problem was presented by Fernandez *et al.* [8], which consists of the application of the non-outranked sorting genetic algorithm to public project portfolio selection.

For the organization of this paper, we chose IMRAD structure [9]: introduction, methodology, results and discussion. This structure is part of the uniform requirements for manuscripts submitted to biomedicine journals from the International Committee of Medical Journal Editors. The adoption of this framework should facilitate the information storage and retrieval in international databases by search engines for research purposes like systematic reviews and meta-analysis.

2. Methodology

The selection process of FAPT is characterized in the study by two steps. The first step comprises of a subjective analysis of the project judged by a technical team of the organization resulting in a maximum rejection score for each project; the accepted projects go through a selection step. The second step consists of the selection of the projects that will receive the grant from the foundation. In this stage, the value and benefit of each project are estimated.

It is worth mentioning that Research Foundations commonly carry out the selection process task manually. The resources distribution requires the selection process to be accurate and organized, sorting the projects by priority and overlooking knapsack problem. The proposed solution aims to generate results more accurately, quickly and efficiently.

2.1. The Tabu search

The solution propose to decide the problem of research projects selection by the use of Tabu Search meta-heuristic. Originally proposed by [1], the Tabu Search meta-heuristic is commonly used to solve combinatorial problems. The method guides a local search algorithm in a search space, exploring the space of solutions moving from one solution to another best neighborhood.

The Tabu Search (TS) algorithm starts at a random initial solution. The initial position and all subsequent solutions obey the well satisfactorily selection criteria. As shown in the TS Procedure below, the TS algorithm explores each iteration, a subset V of $N(s)$ neighborhood of the current s solution. The member s' of V with best region value under the function $f(.)$,becomes the new current solution, even if $f(s) > f(s')$, inducing a minimization problem.

The criterion for choosing the best neighborhood is a strategy to escape from great local, being necessary to prevent the possibility of returning to a solution already previously generated. The Tabu list serves as a fixed-size queue, being always filled. When a new motion is added to the list, the oldest exit.

The application method is settled based on the following points:

1. using descent heuristics;
2. moving to the best neighborhood;
3. creating a Tabu list;
4. defining a criteria for aspiration.

The method of Tabu Search was initially applied using a mathematical formulation for the proposed model, where:

Pij = score of the i project from j area;

n = total number of projects;

m = total number of areas;

Vij = value of i project from j area;

Xij = Î{0,1}, indicates whether the i project from j area will be considered (1) or (0);

Zj = maximum number of projects from j area;

Kj = the maximum value of projects from j area;

R = total resource available for the public call.

The objective function is presented in Figure 1. The function aims to select the highest number of projects by points (benefit).

$$Maximize\ Points\ \sum_{i=1}^{n}\sum_{j=1}^{m} PijXij$$

Fig. 1: Objective function.

In addition to the objective function, some necessary constraints were formulated to the selection process. The equivalent formulation to selecting projects in a given area is showed in Figure 2.

$$\sum_{i=1}^{n} Xij \leq Zj, \forall j = 1, \dots, m$$

Fig. 2: First constraint.

The second constraint is showed in Figure 3. The sum of the values of the selected projects must be less than or equal to the maximum value allowable by area.

$$\sum_{i=1}^{n} VijXij \leq Kj, \forall j = 1, \dots, m$$

Fig. 3: Second constraint.

Finally, the third and last constraint is showed in Figure 4. The sum of the values of the selected projects must be less than or equal to the maximum value allowable for the public call.

$$\sum_{i=1}^{n}\sum_{j=1}^{m} VijXij \leq R$$

Fig. 4: Third constraint.

The Tabu Search algorithm was implemented in this study according to the Procedure below, as defined in the mathematical formulation.

TS Procedure

1. Be s_0 the initial solution;
2. $s^* \leftarrow s_0$; {The best chosen solution until now}
3. Iter ← 0; {Counter of the number of iterations}
4. Best Iter ← 0; {Recent iteration proposed by s^*}
5. Be TS max the maximum number of iterations without s* improvement; {determined by the user}
6. T ← Ø; {Tabu list}
7. Initialize the aspiration function A;
8. While (Iter – Best Iter ≤ TS max) do
9. Iter ← Iter + 1;
10. Be $s' \leftarrow s \oplus m$ the best chosen for V ⊆ N(s) such that the movement m is not in Tabu list ($m \notin$ T) or s' is in accordance with the aspiration criteria *f(s')<A(f(s));*
11. Update the Tabu list T;
12. $s \leftarrow s'$;
13. if *f(s)* < *f(s*)* then
14. $s^* \leftarrow s$;
15. Best Iter ← Iter;
16. end-if;
17. update the aspiration function A;
18. end-while;

19. return *s**;
end TS

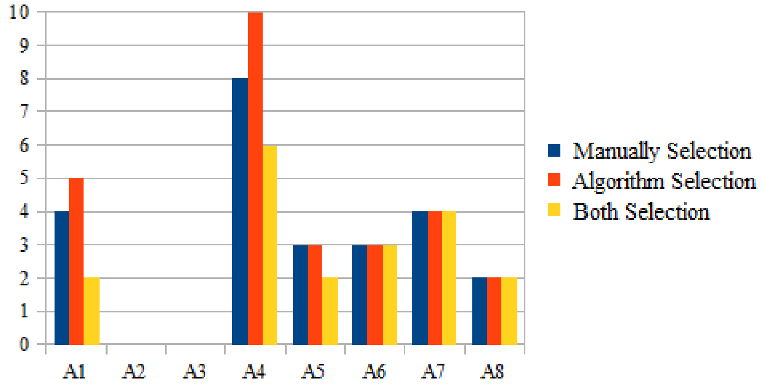

Fig. 5: Amount of selected projects by area.

3. Results

For tests carried out with the algorithm, the projects submitted to the public bid for financial support grant made by FAPT were used as database. The bid consisted of 118 projects registered. The data were adapted to the algorithm with the identification of each project, budget and score related to the benefits thereof. Based on these data the algorithm performed the search and selection of proposals. The algorithm also allowed some criteria to be defined for selection. In addition to the project selection criteria, initial control parameters were determined to the Tabu Search algorithm, as well as following: Tabu value – when the value of the best solution reaches a known lower limit (or near it), it was set to 15; TS max – maximum number of iterations without improvements to reach the best solution value, this value was set to 50.

The Tabu search algorithm developed for the SPRP was implemented in Java, and, in this investigation, ran on a computer with Intel Core 2 Duo T5800, 2.00GHz CPU, 4GB of RAM. The results of the selection analysis conducted by FAPT and performed by the algorithm were shown in Figure 5. The results refers to the second step of the selection process, i.e., after the subjective analysis of projects and the judgement by a technical team of the organization. In this analysis, we adopted the same criteria used for the edictal to run the algorithm. The selection of the bid sought projects based on the number of registered projects by area, on their score and budget. The manual selection process let projects from Area 2 and 3 without any grant. The selected projects took into account the cost-benefit analysis.

For example, for the area A1 there were four selected projects with a total budget of R$131,239.77. Based on the same budget, the algorithm was set to select all projects from A1 so it does not exceed the budget, but maximizing the number of projects to receive the financial grant. Therefore, the same approach was applied for all areas. The results are shown in Figure 5.It is worth noticing that a larger amount of projects were selected by the technique for areas A1 and A4 than the manual process. Hence, optimizing the number of contemplated projects criterion. The algorithm took 1 to 2 seconds to generate all the results.

The algorithm may also generate results using others criteria, e.g., it can be used in the first step of the selection process. Hence, there is the possibility to select grants as needed. For example, selecting projects by dividing the total amount R$600,000.00, by area, R$ 75,000.00, where the results are showed in Figure 6.In this case, projects from Area 2 and 3 were contemplated.

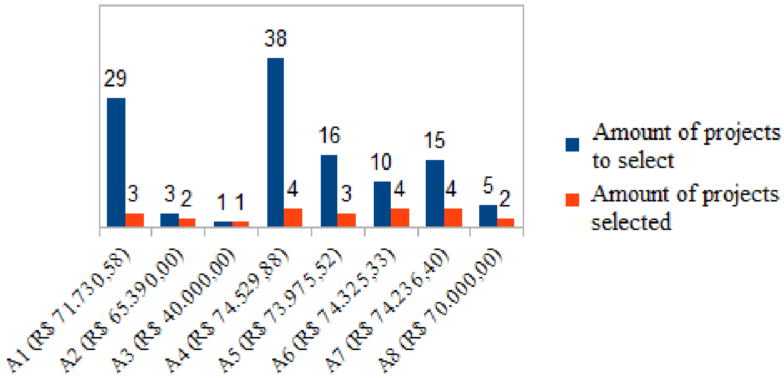

Fig. 6: Projects selected by the algorithm dividing the total value of the grant by area.

Another example is the score-based selection of projects considering the cost-benefit relation of each project, see Figure 7. In this example, the algorithm selected 25 projects, exceeding in one project the manual selection.

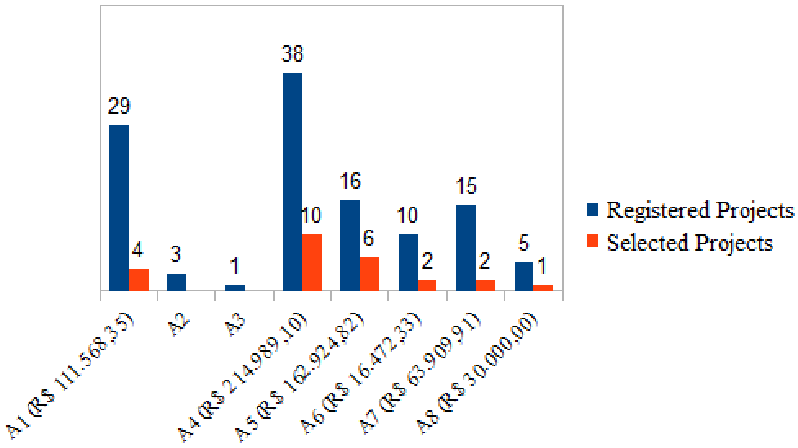

Fig. 7: Projects selected by the algorithm arranged byrating points.

4. Discussion and Conclusion

The results achieved with the Tabu Search algorithm in this investigation demonstrated important facts from an operational and cost-effective point of views. Hence, the importance of techniques for the decision-making process is established for the Selection Problem of Research Projects (SPRP). The experiment reveals that the implemented technique is able to solve the problem, in compliance with the rules established by the bid. This approach may benefit the Research Foundations minimizing working time and other costs.

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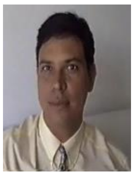

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