Proceedings of the 2019 Winter Simulation Conference
N. Mustafee, K.-H.G. Bae, S. Lazarova-Molnar, M. Rabe, C. Szabo, P. Haas, and Y.-J. Son, eds.

Physician Scheduling With Stochastic Patient Flow: A Tabu Search With Computing Budget Allocation Technique

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ABSTRACT

Physicians are critical resources for hospitals. The scheduling of physicians has great impact on the hospital efficiency and the duration of patient treatment. In this research, we consider the physician scheduling problem in the pretreatment phase for cancer patient. The goal is to generate a weekly cyclic physician schedule that shortens the pretreatment duration of patients. Due to the high uncertainties associated with the patient arrival day, profile and type of cancer, the problem is a stochastic simulation optimization problem. We propose a stochastic tabu search approach. The tabu search is coupled with several computing budget allocation techniques to efficiently use the simulation budget to mitigate the effect of noise. Experiment results show that the proposed approach is able to obtain high quality solution with a large saving of simulation budget.

1. INTRODUCTION

When a patient arrives at the radiotherapy center, he/she is assigned to a physician based on the cancer specialization and the physician's availability and quota for new patients. Before the patient starts the treatment plan, the patient should undergo a pretreatment phase. This phase requires four tasks provided by the assigned physician: consultation, scan contouring, dosimetry and preparation of treatment plan. We refer the readers to Niroumandrad and Lahrichi (2018) for more details of the pretreatment phase.

The physician schedule is tasks-based, i.e., a physician performs a specific task in one period (one day, or half-day). In practice, all the tasks are scheduled in each week. The goal is to generate a weekly cyclic schedule which repeats in all the year for all the physicians to minimize the duration of patient treatment. The satisfactory of physicians is also considered in the objective function. Given that uncertainties exist in the patient arrival day, profile and type of cancer, a schedule is subjected to randomness in the objective value. This characterizes the problem as a stochastic simulation optimization problem.

2. LITERATURE REVIEW

To tackle the black-box simulation optimization problems, several families of techniques, such as random search approach, partition-based algorithms and meta-heuristic approach, have been adopted with the Monte Carlo based techniques that account for the noise of simulation replications. Compared to the deterministic counterpart, the principal challenge is that the simulation noise may mislead the search direction of the optimization algorithms and introduces difficulty in converging to high quality solution. Though simulation noise can be mitigated by increasing the number of replications, the long simulation

time limits the total available budget of the solution approach. Hence, it is required an efficient usage of the simulation budget in the optimization procedure.
Several studies have investigated the integration of computing budget allocation technique with optimization algorithms to guarantee the correctness of the search direction to improve the solution quality. The budget allocation techniques are mainly referred to the ranking and selection procedure, which minimizes the total budget to select the best from a set; and the optimal computing budget allocation approach, which maximizes the probability of correct selection given a total budget. Successful integrations are reported for different optimization algorithms including genetic algorithm, particle swarm optimization and some multi-objective evolutionary algorithms.

3. TABU SERARCH WITH BUDGET ALLOCATION TECHNIQUE

The tabu search we apply is based on the version developed in Niroumandrad and Lahrichi (2018), which has been shown very efficient in comparison with CPLEX in the deterministic problem. For stochastic version, instead of following their approach which allocates simulation budget equally to neighborhood solutions, three computing budget allocation techniques are adopted, respectively: (a) a simple two-stage Top-K allocation; (b) a fully sequential ranking and selection approach (Kim and Nelson, 2001); (c) the OCBA approach proposed by Chen et al.(2000).

The framework of the tabu search integrated with budget allocation technique is described as below:

Step 1: Generate the neighborhood solutions according to the adopted neighborhood structure
Step 2: Evaluate the neighborhood solutions
- ✧ Adopt the budget allocation technique to determine the replication number of each solution
- ✧ Perform the simulation to evaluate the solutions

Step 3: Move to the best non-taboo solution, update the tabu list
Step 4: Stop or go to Step 1

4. NUMERICAL RESULTS

The proposed algorithm is tested with a real-world scheduling problem in the Center Intégré de Cancérogogie de Laval (CICL), which is a cancer treatment center in the Montréal region, Canada. There are nine physicians with different expertise. Different instances are generated with different number of patients arrived within a week. For each instance, fifty patient arrival scenarios are generated based on the week data in the previous year, this means that for each solution the maximum number of scenario is fifty. Results show that by integrating the computing budget allocation techniques, the tabu search is more efficient. On the one hand, given the same amount of total simulation budget, the proposed methods are able to converge faster and obtain better solution than that using the equal allocation strategy with all fifty scenarios. On the other hand, given the same number of iterations, the proposed methods are able to obtain solution as good as that using equal allocation strategy but with substantially less simulation budget.

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