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A Differential Evolution with Scatter Search for Project Scheduling

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Abstract. The resource-constrained project scheduling is an important problem for enterprise resource planning. We herein propose a differential evolution with scatter search structure (named by DESS hereinafter) to tackle resource-constrained project scheduling problem. DESS follows the scatter search structure but uses differential evolution (DE) to generate new solutions of SS, and applies 3-opt local search algorithm as the improvement method of SS to transform each trial solution into enhanced trial solution. The proposed DESS is compared with the state-of-the-art algorithms on a set of standard problems available in the literature. The experimental results validate the effectiveness of DESS.

Introduction

Enterprise resource planning (ERP) is an integrated computer-based system used to manage internal and external resources including tangible assets, financial resources, materials, and human resources. The ERP system can aid in the control of many activities, including sales, marketing, delivery, billing, production, inventory management, quality management, and human resource management. As a part of ERP, the classical resource-constrained project scheduling (RCPSP) continues to be an active area. In recent years, this study attracts increasing interest from researchers and practitioners for searching for better solution procedures. However, for the NP-hardness character of the RCPSP, heuristic solution procedures remain as the only feasible method of handling practical larger resource-constrained project scheduling problems. Many researchers had proposed various heuristics and meta-heuristics to solve the underlying RCPSP[1-6]. The Differential Evolution (DE) algorithm was a relative recent heuristic method introduced by Storn and Price in mid-1990s for complex continuous non-linear functions. Lorenzoni et al.[2] and Damak et al.[3] used differential evolution to solve MRCPSP. In this study, we employ DE with scatter search for better performance.

The Resource-Constrained Project Scheduling

The resource-constrained project scheduling problem (RCPSP) can be stated as follows[7]: A single project consisting of a set N of activities, including n real activities and two dummy activities as the start and finish of the project, numbered from 0 to $n+1$, has to be scheduled on a set R of constrained renewable resource types subject to finish-start-type precedence constraints with time lag of zero. While being processed, activity j requires r_{jk} units of resource-type $k \in R$ in every time unit of its deterministic and non-preemptive duration d_j. Capacity of resource k is constant throughout the project horizon and limited to R_k. The dummy start and finish activities have zero duration and resource usage, while the real activities have positive duration and non-negative resource usage subject to $r_{jk \leq R_k}, j \in N, k \in R$. The objective of RCPSP is to find a precedence and resource-feasible schedule S, defined by a starting times vector $s=(s_0, \ldots s_{n+1})$, such that the project makespan $T=s_{n+1}$ is minimized.

The Proposed DESS for RCPS

We herein proposed a mimetic algorithm which employed the mutation and crossover operator of DE to generate new solutions of SS for the RCPSP problems. In SS, path relinking generates paths between and beyond the selected solutions in the neighborhood space and then sampling solutions in the path. However, this exploration method will generate a large of number trial solutions, and may lead to the massive unuseful information with too many evaluations.

To overcome the drawback of path relinking, and to maintain the diversification and intensification of RefSet, we need to employ a simple and effective solution generation strategy. DE is a simple and easy-used evolutionary algorithm and has the advantage of fast convergence rate. Therefore, we proposed a mimetic algorithm DESS which employed DE's new solution generation method to SS for RCPSP, aiming to obtain a fast convergence exhibited by DE while keeping a better diversification. In DESS, We introduced the SS to provide a framework, and employed the mutation and crossover operator of DE to generate the new trial solutions of SS, and use 3-opt local search algorithm as the improvement method of SS to improve the quality of the schedules. Fig. 1 shows the flowchart of DESS. The representation and decoding procedure and the SS, the DE and the local search strategy used in DESS are detailed below.

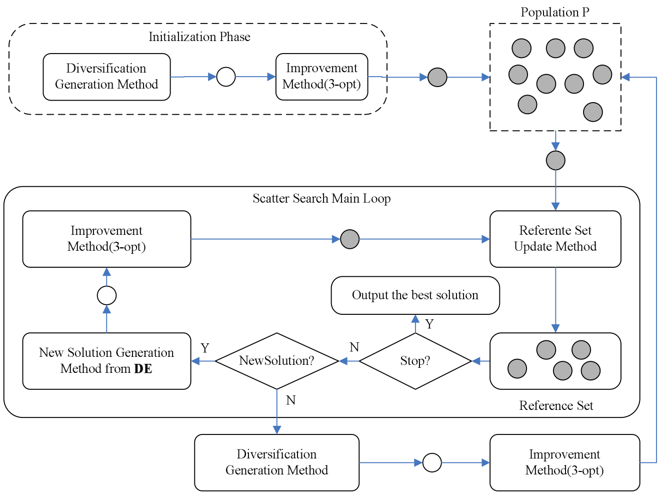

Figure.1, The flowchart of DESS

We employed SS as the algorithm framework of proposed DESS. To obtain better performance of solution, we given an advanced design of SS in the DESS as follow.

Step 1. Use the diversification generation method to construct the initial solution set of SS.

Step 2. Select best solutions and diverse solutions to build the "high-quality" reference set RefSet_1 and "diverse" reference set RefSet_2.

Step 3. Apply the solution generation method and the improvement method to obtain one or more trial solutions.

Step 4. Use the trial solutions to update the RefSet_1 and RefSet_2. Repeat Steps 3, 4 until the reference set does not change.

Step 5. Restart from Step 1, create a new initial solution set, containing the individuals currently in the reference set. Stop when the stop criteria are met.

The Experimental Study

In this section, we present the results of the computational studies concerning the algorithm introduced in previous sections. For a fair machine-independent comparison, we limited the number of generated and evaluated schedules in DESS to 1000, 5000 and 50000, respectively. And this limitation allowed us to compare results with those obtained for several RCPSP heuristics from the literature which were tested for the evaluation study of Kolisch and Hartmann[1]. The suitable control parameter values of DESS for each problem were found by trying out a list of different control parameter values.

Table I-IV listed the performances of DESS and several RCPSP heuristics from the literature with 1000, 5000 and 50000 evaluated schedules. The considered algorithm here that were used to compared with DESS are genetic algorithms[4,6], local search[5], etc. The lower bound based results for the instances with 60 activities can be found in Table I. DESS ranks 2nd and 1st for 1000 and 5000 schedules respectively, and ranks 1st for 50000 schedules. Table II indicated the results for $J120$, we can see that DESS outperformed all other algorithms for 1000, 5000 and 50000 schedules respectively.

TABLE I. AVERAGE PERCENT DEVIATIONS FROM SET $J = 60$

Algorithm	References	Schedules		
		1000	*5000*	*50000*
DESS	This study	11.13	10.72	10.49
Enhanced Scatter Search	Mobini[1]	11.12	10.74	10.57
GAPS	Mendes et al.[6]	11.72	11.04	10.67
GA-DBH	Debels et al. [4]	11.45	10.95	10.68
Scatter Search-FBI	Debels et al. [1]	11.73	11.10	10.71
GA, TS-path relinking	Kochetov and Stolyar [5]	11.71	11.17	10.74
GA-FBI	Valls et al. [1]	12.21	11.27	10.74

TABLE II. AVERAGE PERCENT DEVIATIONS FROM SET $J = 120$

Algorithm	References	Schedules		
		1000	*5000*	*50000*
DESS	This study	34.02	32.26	30.53
GA-DBH	Debels et al. [4]	34.19	32.34	30.82
Enhanced Scatter Search	Mobini[1]	34.51	32.61	31.37
GAPS	Mendes et al.[6]	35.87	33.03	31.44
Scatter Search-FBI	Debels et al. [1]	35.22	33.10	31.57
GA-FBI	Valls et al. [1]	35.39	33.24	31.58
GA, TS-path relinking	Kochetov and Stolyar[5]	34.74	33.36	32.06

From the above results, we can see that DESS can obtain better solutions than any of the heuristic algorithms referred to in Table I-II for the large-sized problems $J60$ and $J120$. DESS is an effective method for RCPSP which combined the advantages of SS and DE. SS explicitly maintain a “diverse” reference set to help algorithm for exploring new areas in the search domain and avoid early search stagnation, and the high quality solutions in the RefSet guarantee that algorithm could converge to the optima. Using the differential information in DE could help DESS obtain fast convergence. 3-opt adopted here as the improvement method can exploit the neighborhood of the best solutions found during the search to obtain better solutions. In conclusion, the proposed DESS hybridizing SS with DE can balance between exploration and exploitation of RCPSP.

Conclusions

In this study, we proposed a memetic algorithm that combined scatter search (SS), differential evolution (DE), and a local search strategy (3-opt) to tackle resource-constrained project scheduling problem (RCPSP) from ERP field. The computational results had showed that DESS is capable of providing near-optimal solutions for small-sized RCPSP and outperformed other heuristic algorithms for some large-sized RCPSP. The further studies should focus to enhance the applicability and efficiency of the proposed DESS to various complex real-world schedule problems from ERP.

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