A Histogram Estimation of Distribution Algorithm for Resource Scheduling

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ABSTRACT

Resource scheduling is always a highly concerned NP-hard problem in operations research. Taking advantage of estimation of distribution (EDA) algorithms, this paper develops a histogram EDA (HEDA) for resource scheduling. First, a histogram-based distribution model is adopted. The height of each bin in the histogram is updated using the accumulation strategy according to the ranking of individuals. Second, a repair strategy is applied to fix all the newly sampled solutions into feasible ones that satisfy the deadline constraint. Experimental results show that the proposed HEDA is promising, particularly in large-scale instances.

CCS CONCEPTS

• **Computer systems organization** → *Planning and scheduling, Search methodologies*

KEYWORDS

Scheduling, estimation of distribution algorithms, histogram

1 INTRODUCTION

Resource scheduling is commonly seen in many application areas such as insurance investment planning [1], transportation [2], project scheduling [3], and so on. In many cases, resource scheduling problems are NP-hard [4]. Evolutionary algorithms (EAs) have been found to be an effective way to tackle resource scheduling problems [4].

Recently, estimation of distribution algorithms (EDAs) have emerged as a special kind of EAs that evolve the population by estimating the probability distribution of populations and sampling new offspring based on the distribution [5-7]. The effectiveness of EDA for resource scheduling has also been verified by using a Boltzmann-based model [4]. However, with growth of problem scale, it remains a critical issue to improve the search efficiency of EDAs for resource scheduling problems.

This paper proposes a histogram estimation of distribution algorithm (HEDA) for resource scheduling. HEDA uses the histogram-based distribution as the probability model. Following the accumulation rule [7], the histogram is updated according to the rank of individuals in the population. In addition, a repair strategy is applied to fix all the newly sampled solutions into feasible solutions. As the update of the histogram-based model is time-efficient, and the repair strategy can guarantee the feasibility of the newly generated offspring, the proposed approach becomes efficient. Experiments are conducted on 24 instances. Compared to the Boltzmann-based EDA [4], HEDA yields better performance particularly in large-scale instances.

2 MATHEMATICAL FORMULATION

Assuming that there are n jobs and each job is independent, r_i denotes the resource allocated to job i, $t_i(j)$ denotes the process time of job i using resource j, w_i denotes the cost weight of job i, and d denotes the deadline. The resource r_i allocated to job i belongs to $\{1,2,\ldots,k_i\}$. In addition, the time constraint is given by:

$$\sum_{i=0}^{n-1} t_i(r_i) < d \tag{1}$$

The objective is to minimize the total cost of scheduling subject to the above resource and time constraints.

$$min \sum_{i=0}^{n-1} w_i r_i \tag{2}$$

```
01: procedure HEDA
02:     initialize histogram model;
03:     while terminal condition not met
04:        sample new population;
05:        repair solutions;
06:        evaluate the solutions;
07:        save the dominant solutions;
08:        update histogram model;
09:     end while
10: end procedure
```

Figure 1: Pseudo code of HEDA

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†The full version of the author's guide is available as acmart.pdf document
[1]It is a datatype.

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```
procedure repair
for each individual
    if complete time > deadline
        for each job i (i = 0, 1, ..., n − 1)
            pseudo utility pu_i = (t_i(r_i) − t_i(k_i)) / (k_i − r_i) (0, if r_i = k_i);
        end for
            rank r_i according to pseudo utility and store in seq_i;
        j = 0;
        while complete time > deadline
            r_{seq_j}++; if r_{seq_j} = k_{seq_j}, j++;
        end while
    end if
end for
end procedure
```

Figure 2: Pseudo code of solution repair

3 HEDA FOR RESOURCE SCHEDULING

The pseudo codes of the proposed HEDA and the repair strategy are given in Fig. 1 and Fig. 2, respectively. The most important part of HEDA is the update of the histogram model. The histogram model has totally $\sum_{i=0}^{n-1} k_i$ bins. During each generation gen, the height $H_{i,gen}(j)$ is updated by

$$H_{i,gen}(j) = \alpha Hnew_{i,gen}(j) + (1-\alpha)H_{i,gen-1}(j) \ \# \ (3)$$

where $\alpha (0 < \alpha < 1)$ is accumulation rate, and $H_{i,gen-1}(j)$ is the height of resource j for job i in the histogram in the last generation. $Hnew_{i,gen}(j)$ is calculated as follows. First, the best s individuals in the current generation are selected as the dominant individuals. Then for the l-th best individual ind_l, the corresponding increment is calculated by

$$Hnew_{i,gen}(j) = \sum_{l=1}^{s} \Delta H_{i,j,l} \quad (4)$$

In following way, the higher ranking of the individual, the more increment it brings to the bin.

$$\Delta H_{i,j,l} = \begin{cases} 0, & \text{if } r_l \neq j \text{ for } ind_l \\ \dfrac{2(s-l+1)}{s(s+1)}, & \text{if } r_l = j \text{ for } ind_l \end{cases} \quad (5)$$

New solutions are generated by sampling on the histogram model with the roulette wheel selection scheme. In addition, a solution will be mutated with a mutation rate μ. In this paper, the accumulation rate α is set to 0.2, the mutation rate μ is set to 0.05, the population size is set 100, and the top 50% of the population is selected as the dominant individuals.

4 EXPERIMENTAL RESULTS

Based on the benchmark in [4], we compare the HEDA with the Boltzmann-based estimation of distribution algorithm (BDEDA) [4]. BDEDA has been proven better than ant colony system (ACS), conventional genetic algorithm (CGA), univariate marginal distribution algorithm (UMDA), and Markov estimation of distribution algorithm (M_k-EDA) [4]. Table 1 shows the experimental results. Here 4*10 means that the problem has 4 resources and 10 jobs. It can be seen that the proposed approach performs better on 15 out of the 24 instances. In particular, on the 18 larger-scale instances, HEDA performs better on 15 instances. These results verify that the proposed HEDA is promising especially on large-scale instances by virtue of its high diversity.

Table 2: Comparison of Coefficients from Atomistic

Scale	BDEDA	HEDA	Scale	BDEDA	HEDA
	198.53	199.31		**410.48**	413.53
4*10	**296**	297.66	**4*15**	**510.9**	514.7
	171	171		**651.85**	653.9
	259.15	1080.32		1080.32	**1027.66**
7*10	620.18	**587.18**	**7*15**	1376.25	**1345.55**
	194.63	**188.45**		873.5	**793.05**
	853.68	948.66		1213.45	**1067.07**
10*10	1236.52	**1157.59**	**10*15**	1849.08	**1733.95**
	403.39	**215.27**		2297.66	**2274.16**
	1817.77	**1384**		3124.33	**873.57**
50*5	1806.43	**1389.07**	**50*10**	3118.53	**2304.8**
	1851.1	2199.1		4372.26	**3764.83**

5 CONCLUSIONS

This paper proposed a HEDA algorithm for resource scheduling. Experimental results show that the HEDA is promising especially in large instances.

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