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DEVELOPMENT THE MULTI MODE RESOURCE CONSTRAINED PROJECT SCHEDULING MODEL AND SOLVING IT WITH BATS ALGORITHM

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ABSTRACT

Decision-making and optimization issues constitute much of the problems that everyone in the scientific and work life involved with them. Project scheduling regarding limited resources is one of the issues that have a rich research background. Many articles and books have been published in this area, which is evidence of the importance of this issue. In this study, project scheduling problem with limited resource with regard to important goals such as minimizing the time of the project completion and minimize the total cost of the project was considered that is an important objective in the real world and project managers are always looking for the best spot on time – cost. In addition, all renewable and non-renewable resources were considered for a more comprehensive model and the problem was developed in such a way that would be applicable to the real world.

Bats algorithm is used for solving the proposed model that so far, this new, powerful, Meta-heuristic algorithm has not been used for solving these issues and the results of the performance of this algorithm is compared with NSGA - II and PSO algorithms. The results indicate the high performance power of this algorithm in solving the proposed problem as well as these types of issues.

Keywords: Project Management, Project Scheduling, Resource Constraints, Bat Algorithm, Multi-Objective

INTRODUCTION

Since 1950, numerous articles have published in this area and it is still on, which is evidence of the importance and necessity of carrying out future research in this field. If, available resources planning in many projects have been correct and there is not a shortage of resources, we would not confront with issues such as the extra costs, a delay in the project completion time.

Resource Constrained Project Scheduling Problem (RCPSP) is one of the very famous and discussed problems in the field of operations research and projects management. These issues are considered for two reasons: First, they are diverse due to the different conditions and industrial applications in terms of objective function, characterization activities, sources, and prerequisite relationships and second, due to the Np-hard nature of the issues, researchers were always looking to provide more efficient solutions for solving these problems [1].

In this paper, bat meta-heuristic algorithm or bat algorithm have been introduced by Yang in the year 2010 and have been designed based on the principles of bats. This optimization algorithm is operating by using the principle of echoes of the bat and receiving sound by this bird. Bats are amazing creatures that can hunt their prey in total darkness with the publication of noise and receiving it. They also can pass the obstacles with using noise publication or pass from the small cracks easily. Using the same principle, bat algorithm has been used to optimize the complex issues. Bats send high pulse of sound and then listen to its echoes. Pulse of bats is different which is related their hunting strategy. Many of bats use frequency with short wavelength while in most cases, some of the bat species use signals with fixed frequency for echo. Signals bandwidth is different and depends to the species and type of bat [2].

Bats algorithm (Algorithm studied in this study)

Bats are amazing animals. They are the only mammals that have wings as well as advanced ability in echolocation. It is estimated that there is almost 996 different kinds of bats that make 20 % of the total of the mammals (1, 2).their size is changed from tiny bee bat (approximately 1.5 to 2 g) to giant bats with the wings of 2 meters and approximate weight up to1 kg. Small bats usually have an arm length as almost 2.2 to 11 cm. Most of the bats use echolocation to a certain extent; of all the bat species, small bats are considered as a famous example because these bats use echolocation comprehensively against fruit bats [4].

Bat algorithm

If we imagine some features related to echolocation of small bat, we could create inspired algorithms or various bat algorithms. For simplicity, now we use approximate and imagined rules as the following:

1. All bats use echolocation to sense the distance and also "know" the difference between the food / prey and background obstacles as magic form.
2. Bats fly randomly with the speed of vi, position of xi, frequency of fmin, variable wavelength and high of A0 to search the prey. They can regulate automatically the wavelength (or frequency) relating to their send pulse and the rate of send pulse due to near target.
3. While, height may change in different forms, we assume that the height change from the (positive) value of A0 to the fixed minimum value of Amin.

Another clear simplification is that following radiation is not used in estimation of regency time and three-dimensional topography. While this can be a good feature for use in computational geometry but we do not use it because it has broader calculation in the multi-dimensional cases.

In addition to this simplified assumptions, we can also use the following approximation for simplicity's sake. In general, the frequency f in the range of $[f_{\min}, f_{\max}]$ is corresponding to a range of wave length in the range of $[\lambda_{\min}, \lambda_{\max}]$. For example, frequency range of $[20\text{kHz}, 500\text{kHz}]$ is corresponding to wave length range from 0.7 to 17 mm.

For a given problem, we can use any wavelength for simplicity of execution. During the execution, we can adjust the range with setting the wavelength (or frequencies) and differentiable range (with the highest wavelength) should be chosen in a way that is comparable to the size of the desired range and then be adjusted by switch to the smaller range.

In addition, there is not necessity to use the wavelengths. Instead, we can change the frequency with fixing wavelength. This is because λ and f are linked due to the fixed λf. We use this procedure in our implementation.

For simplicity, we can assume that $f \in [0, f_{\max}]$. We know that higher frequencies have shorter wavelengths and pass from less distance. In bats, a few meters are a normal range. Pulse rate may be in the range of $[0, 1]$ that 0 means no pulse and 1 means maximum rate of sending pulse.

According to this approximations and ideas, radical steps of bat algorithm (BA) could be summarized as the shown pseudo code in diagram 1.

- Proposed algorithm for solving the case study of research

Bat algorithm steps to resolve the proposed issue are as follows:

1 –the first step is setting initial parameters of algorithm which include the following:

- The number of bats
- The number of repetitions
- The coefficient of reducing loudness
- The coefficient of reducing pulse
- The lower limit of frequency
- The high limit of frequency
- Archive capacity

2. The second step is the algorithm of initial population production that takes place randomly

3. In the third step, the main ring of algorithm is carried out in a way that the following is updated according to per bat:

4. If you make a stop condition (in which the number of repetitions of a given issue, such as 1000 and 5000 will be considered.) The problem is stopped and otherwise goes back again to the major loop step.

The performance of bats algorithm in solving problems of base RCPSP

According to the cases mentioned in the previous chapter, first work regarding to the algorithm of regulating initial parameters to resolve the issues is with these algorithms. As mentioned in the third chapter, this algorithm has several initial parameters that setting the parameters by solving various issues according to the literature as follows.

```
Objective function f(x),   x = (x_1, ..., x_d)^T
Initialize the bat population x_i (i = 1, 2, ..., n) and v_i
Define pulse frequency f_i at x_i
Initialize pulse rates r_i and the loudness A_i
while (t <Max number of iterations)
Generate new solutions by adjusting frequency,
and updating velocities and locations/solutions [equations (2) to (4)]
    if (rand > r_i)
    Select a solution among the best solutions
    Generate a local solution around the selected best solution
    end if
    Generate a new solution by flying randomly
    if (rand < A_i & f(x_i) < f(x_*))
    Accept the new solutions
    Increase r_i and reduce A_i
    end if
Rank the bats and find the current best x_*
end while
Postprocess results and visualization
```

Figure 1: Pseudo code of the bat algorithm

Table 1: Initial parameters settings of bats algorithm

parameter values	the name of parameters
20	the number of bats
0.5	The coefficient of reducing loudness
0.5	The coefficient of reducing pulse
0	The lower limit of frequency
2	The high limit of frequency
50	Archive capacity

After setting the parameters, we should solve the problems with standard algorithm that at first, the results of bats algorithm is bring for the base RCPSP. The results are for the standard issues of the internet library PSPLIB which are obtained from j30, j60, j90, j120 collections. The results are repeated according to 5000 and compared with the newest algorithms that are used for this issue up to now. It should be noted that optimal answers for j30 issues are obtained from literature, therefore the low limit for comparison of algorithms in these set of issues is considered optimal answer.

Initially, the results of bats algorithm for the problems of basic RCPSP are showed. Results for standard problems PSPLIB Online Library are from j30, j60, j120, and j90. Results are sorted based on 50,000 repetitions and are compared with a new algorithm that has been used for this problem. It should be noted that optimal answers are obtained in the literature of an issue for j30 problems. Thus, the lower limit for the optimum algorithm on these same issues (optimal) is considered. In j60, j90, and j120 problems there is still no way to find the optimal solutions, thus, in this class of problems, the lower limit of the solutions using the critical path is considered. In order to answer these questions using the critical path method, resource constraints are considered and problems have been implemented without resource constraints. Then finally the average relative deviation of the solution is obtained and has been appointed in Tables 2, 3, and 4.

According to Table 2, it is clear that the algorithm had only 0.27% difference from lower limitation of J30 series problems based on 1000 replication and it could allocate the 4th rank to itself between the latest algorithms for solving these problems that indicates a good result. But for the larger problems such as j60 and j120 algorithm has done much better and could allocate the second rank to itself between the latest algorithms for solving these problems that indicates the power of this algorithm in solving problems with small and large scale in these series of problems.

As is evident from Table 3, the algorithm has done well to solve this set of problems and the deviation from the lower limit of the range of problems is the same answer based on the critical path with no resource constraints and was only 11.33% based on 1000 repetition. If we sort algorithms in the above table with 50,000 times repetition, this powerful algorithm in the first place is a series of problems j60 that in several articles is based on 50000 repetitions and in this research and some articles the basis for speed to reach the best answers and the number of repetitions are selected. Therefore, in this study 1000 repetitions were used to sort the above table. In the following, the results of solving algorithm for the problems j120 series were given.

The proposed algorithm allocated the third rank to itself in solving these series of problems that in fact, the deviation was 35.33% from lower limitation in 1000 times repetitions that exposes a very good performance of the algorithm in solving these basic RCPSP big problems.

Table 2: Results of algorithm performance and comparing it in j30 series solving problems

Authors and Year of publication	The used algorithm name	Resource	Iteration- The number of repetitions		
			1000	5000	50000
GA-TS-path relinking-2003	Genetic algorithm& Tabu search	[91]	0.10	0.04	0.00
Kuolinas et al-2014	PSO-HH PSO based Hyper Heuristic	[93]	0.26	0.04	0.01
Byranvand et al,2015	Bats Aglorithm	This paper	0.27	0.06	0.01
Vallas et al -2008	Hybrid Genetic Algorithm	[94]	0.27	0.06	0.02
Vallas et al-2011	GA-FBI	[95]	0.34	0.20	0.02
Wang et al-2012	SFL	[96]	0.38	0.14	---
Ziarati et al-2011	BA-FBI	[97]	0.42	0.19	0.04
Proon et al -2011	Gans	[98]	1.83	1.27	0.71

Table 3: Results of algorithm performance and comparing it in j60 series solving problems

Authors and Year of publication	The used algorithm name	Resource	Iteration- The number of repetitions		
			1000	5000	50000
Debels and anhoucke-2007	Genetic algorithm	[91]	11.31	10.95	10.68
Byranvand et al,2015	Bats Aglorithm	This paper	11.33	10.98	10.69

Vallas et al -2008	Hybrid Genetic Algorithm	[94]	11.56	11.10	10.74
Debels et al-2006	Scatter Search	[99]	11.73	11.10	10.71
Kuolinas et al-2014	PSO-HH PSO based Hyper Heuristic	[93]	11.74	11.13	10.68
Chen et al-2010	ACOSS	[100]	11.75	10.98	10.67

Table 4: Results of algorithm performance and comparing it in j120 series solving problems

Authors and Year of publication	The used algorithm name	Resource	Iteration- The number of repetitions		
			1000	5000	50000
Kuolinas et al-2014	PSO-HH PSO based Hyper Heuristic	[93]	35.20	32.59	31.23
Byranvand et al,2015	Bats Aglorithm	This paper	35.33	33.29	32.10
Wang et al-2012	HEDA	[101]	35.44	33.61	#
Chen- 2011	JPSO-PSO	[101]	35.71	33.88	32.89
Ziarari et al-2011	BA-FBI	[97]	37.72	36.76	34.55
Hartmann-2002	GA-Activity List	[102]	39.37	36.74	34.03
Kuolinas et al-2014	PSO-HH PSO based Hyper Heuristic	[93]	35.20	32.59	31.23

CONCLUSION

In this paper, the performance of meta-heuristic bats algorithm in solving basic RCPSP problems has been evaluated. The results show the strong performance of this algorithm in solving these problems. In future research, other problems such as MRCPSP and MORCPSP can be solved using this algorithm to have a more comprehensive review in solving more complex problem of RCPSP.

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