PROJECT MANAGEMENT OPTIMIZATION WITH CONSTRAINED RESOURCES USING GENETIC ALGORITHMS

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Abstract:

Scheduling of a project is difficult because of its constraints and complex structure. At first, mathematical methods were used but they failed. Nowadays, heuristic methods have been used with a well-determined heuristic function. In this paper, the bridge construction problem and the masonry construction problem which are defined in literature are scheduled with proposed genetic algorithm method. The solutions are represented in a chromosome and the gene values point out the order of activities to start when their constraints are satisfied and enough resources are available. The aim is to minimize the project duration as much as possible by considering the constraints. From this point, the fitness function value is the duration of whole project in proposed algorithm. At the end, the solutions are compared with earlier studies and the results show that the best solution is always obtained with the proposed algorithms. In fact, the execution times of the proposed methods are less than one second.

Keywords: Project management, resource constraints, genetic algorithm

1. Introduction

In last few decades, the people's creativity has been grown by the technologic improvements in computer science and the methods have been arisen. One of this is artificial intelligence (AI) area. AI proposes a solution method by using people's knowledge, inference, and analysis attributes in digital environment. Too many AI methods have been improved which are artificial neural networks, expert systems, fuzzy logic and heuristic methods such as genetic algorithms (GA), tabu search, simulating annealing, ant colony. These methods are used in medical, communication, manufacture, industrial and automation area.

Scheduling of a project by hand is difficult because of its constraints and complex structure. In general scheduling means completing the jobs within given constraints by allocate the resources optimally. There are jobs to be achieved, resources that are needed, and constraints that must be obeyed. Resource scheduling problems have been studied so much because of their practical applications. Earlier the mathematical methods were used to solve these problems, but they failed because of the complex structure of scheduling. Later, heuristics methods have been used such as simulated annealing, tabu search, honey bee optimization, because to find an optimal solution such as the shortest path which satisfies the whole constraints require logical reasoning and searching possible solutions with a well-determined heuristic function. Nowadays, GA has been chosen because of their four main characteristics (Goldberg, 1989):

- It uses a coding of parameters instead of their real values.

- It evaluates a lot of candidate solutions instead of one solution. By this it can avoid from the local optimum.

- To obtain optimal solution genetic algorithm uses independent fitness function. It doesn't need any derivative or similar information. So it can be used in a lot of problems.

- It shows different approach based on probabilities at every time. So it obtains results that other techniques cannot achieve.

In this paper, first the two-span bridge construction problem then the masonry construction problem is used which are defined in literature. To solve these two problems, an efficient genetic algorithm method is proposed. The problem definition and this method are explained in detail in Section 3. Experiment results and comparing with other studies are shown in Section 4. Finally, the attributes of these method and conclusions are told in Section 5.

2. Related Works

The two-span bridge construction problem was first introduced and solved by Toklu. He used genetic algorithms to solve this problem and each gene's value represents the start day of activities (Toklu, 2002). Zhao and Ru solved this problem with particle swarm optimization (Zhao and Ru, 2008). Their result showed that this method is feasible for applying to scheduling optimization. And then Haddad and his friends solved this problem with honey bee mating optimization algorithms under the constrained/unconstrained resources (Haddad, Mirmomeni, Mehrizi and Marino, 2008).

The masonry construction problem was first introduced by Hinze (Hinze, 1998). Senouci and Naji solved this problem with augmented Lagrangian genetic algorithms. Their proposed method, which considers both resources constrained scheduling and project total cost minimization, uses the quadratic penalty function to transform the constrained resource scheduling problem to an unconstrained one (Senouci and Naji, 2003). And also Haddad and his friends solved with honey bee mating optimization algorithms (Haddad, Mirmomeni, Mehrizi and Marino, 2008).

3. Problem Definitions And Proposed Algorithms

A. Bridge Construction Problem

In this problem, there are eight jobs to complete in the given durations, and also some of these jobs have precedence jobs. These jobs need some resources which are the excavation team, the pier team and the deck team and only one job can use these resources at the same time. These parameters are shown in Table 1.

To solve bridge construction problem genetic algorithms are used. The structures of the proposed genetic algorithm are designed according to the problem structure. These proposed methods are shown below:

A.1. Representation: In this method the solutions of the problem are represented in chromosomes. Deciding the chromosome structure is important for this problem. So this operation should be performed carefully to obtain optimal solutions. In this problem the phenotype of the solution is the working activities with the applicable order to create the bridge. So the genotype must be the order of these activities. In proposed method the chromosomes represent the order of these jobs by considering constraints. The chromosome size is the total number of activities, each gene represents each activity. And this gene values are the order of that activity. In this problem activity A1, B1 and C1 use the same resource so these must be in order to use this resource. These activities are represented in the first three gene of the chromosome and their values are the orders. Activity A2, B2 and C2 also use the same resource. These are also must be in order. The fourth, fifth and sixth gene represent these activities respectively, and their values are the order of these activities with each other. And last two genes are used for activity D1 and D2. The example of the chromosome is shown in Figure 1.

Table 1: Activity properties for the Bridge Construction problem

Activity	Description	Precedence	Duration (days)	Resources usage		
				1	*2*	*3*
A1	Excavation at pier A	-	15	+		
A2	Pier Works A	A1	20		+	
B1	Excavation at pier B	-	10	+		
B2	Pier Works B	B1	30		+	
C1	Excavation at pier C	-	27	+		
C2	Pier Works C	C1	30		+	
D1	Deck AB	A2,B2	24			+
D2	Deck BC	B2,C2	18			+

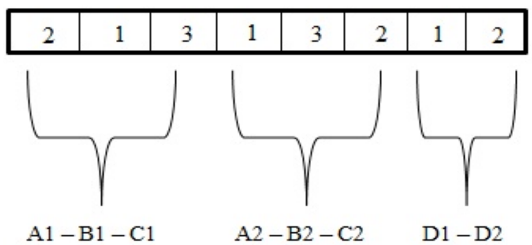

Figure 1. The structure of proposed chromosome for the Bridge Construction problem

In this chromosome first B1 is done then A1 and C1 use the first resource. Then first A2 uses the second resource after its precedence job is finished. Then C2 and B2 use the second resource respectively after their precedence jobs are finished. And finally D1 uses the third resource and then D2 uses the third resource after their precedence jobs are finished.

A.2. Fitness function: In this method the purpose is to calculate how much the chromosomes are suitable. The fitness value for the chromosomes is defined as the whole duration of the plan. So the aim to solve this problem is the minimizing the whole duration as much as possible. In the example of Figure 1, the fitness value calculated as follows:

First the B1 is performed and its duration is 10 day then A1 is performed, it finishes 25th day, and C1 finishes at 52nd day. A2 can perform after A1 finishes, so A2's finish time will be 45, then C2's finish time is 82, and B2 finishes at 112th day. D1 can perform after A2 and B2, so its finish time is 136, finally D2 finishes at 154th day. So the fitness value of this chromosome will be 154.

A.3. Other operations: To select parents roulette wheel algorithm is used. In this algorithm individuals have a chance proportional to their fitness values. The better individuals have much probability to be selected.

In crossover operation, the parents which are selected before reproduce. The operation performs as follows:

The chromosome can be separated from either the first gene or the fourth gene or the seventh gene. There can be one point crossover or two points cross over. The example of two point crossover is shown in Figure 2.

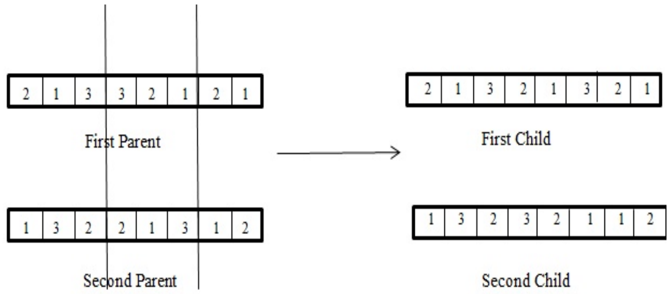

Figure 2. The two point crossover operation for the Bridge Construction problem

In mutation operation, the child's genes are mutated by swapping the orders randomly. The example is shown in Figure 3.

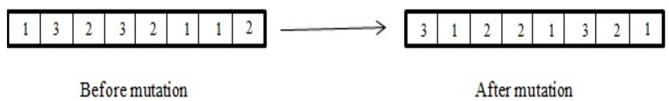

Figure 3. The mutation operation for the Bridge Construction problem

To select individuals for the new generation Elitism is used to survive some of the better parents. The remaining individuals consist of children.

The proposed algorithm finishes when the maximum generation count is reached.

B. Masonry Construction Problem

Another problem is the masonry construction problem. This problem consists of twelve activities with two resources: masons and helpers. Activity durations and their precedence jobs are also identified. The maximum use of masons and helpers at a specific time is five and two respectively. These are shown in Table 2. In this problem the proposed method is similar with the first problem but there are some differences. These differences are explained in detail.

Table 2: Activity properties for the Masonry Construction problem

Activity	**Precedence**	**Duration (days)**	**Resources needed**	
			Masons(M)	***Helper(H)***
A	-	1	2	1
B	A	4	2	1
C	A	2	2	1
D	B	1	1	0
E	B	4	3	0
F	C	3	3	0
G	C	4	1	2
H	C	2	1	1
J	D	2	2	2
K	J,E	6	2	1
L	F,G,H	2	3	2
M	K,L	1	2	1

A.1. Representation: In this problem the chromosome size is the total number of activities. Each gene represents each activity. Unlike the bridge construction problem, the genes value is the order of priority for those events which have the same precedence activity. In this problem activity B and C have the same precedence. D and E have the same precedence. F, G and H have the same precedence. These must be executed after their precedence finishes. The gene value is the priority to be executed if the resources are available for that activity. The example of chromosome is shown in Figure 4.

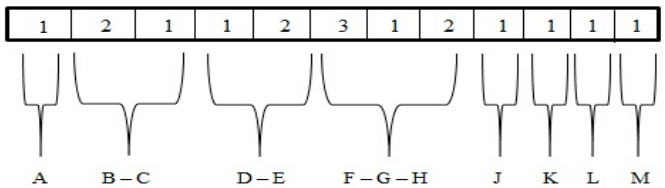

Figure 4. The structure of proposed chromosome for the Masonry Construction problem

In this chromosome first activity A is done. Then B and C are active for execute. First C is tried to be executed if resources are enough for C, then B is tried to be executed if resources are enough for B. These are done again until B and C are done. After B is done, D and E become active. First D is executed if resources are available for activity D, then E is executed. These are done again until D and E finish executing. After C is done, F, G and H are available to be executed. First G is tried to execute if available, then H is chosen after that F is chosen until F, G and H are done. After D is done, J can be executed if there are enough resources. K can be done after J and E finish if resources are available. L can be executed after F, G and H are done if there are enough resources. And finally, M is executed after K and L finish.

B.2. Fitness function: Like the first problem the fitness value of chromosomes is the whole duration of activities and the purpose is the minimizing the whole duration as much as possible. The fitness value is calculated as below:

In each day all the activities are examined one by one depending on their priority values. If an activity is available (it is precedence activity is done) and there is enough resources for that activity, it can start at that day. For the example in Figure 4, first A is executed. Then C is selected. It can be executed because the current resources are enough. Then B is selected. It is executed at the same time because the remaining resources are enough for B. Activity C is finished at 3^{rd} day. After this day, G is selected but it cannot be executed because activity G needs one mason and two helpers. There is not enough helper for G because B doesn't finish and uses one helper at that time. Then H is selected and there is enough resource for activity H so it can be executed. At the same time F is considered but it cannot start because of insufficient resources. But in later when there is enough resource G and F can start. After B is finished at 5^{th} day, D and E can be examined whether they can start or not. These operations are similar for the remaining activities.

A.3. Other operations: In selection operation, the roulette wheel algorithm is used like the bridge construction problem.

In crossover operation, it isn't necessary to cross activity A, J, K, L and M, because they have always the same value which is one. The chromosome can be separated from either the second gene or the fourth gene or the sixth gene. There can be one point crossover or two points cross over. This operation is similar with the first problem's crossover operation.

In mutation operation, child's genes are mutated by swapping the orders randomly. This also is same with the first problem.

In creating the new generation, Elitism is used to survive some of the better parents and remaining consists of children.

Finally, in termination, the algorithm doesn't finish unless the maximum generation count is reached.

4. Experimental Results

To run proposed genetic algorithms first the parameters should be determined. These parameters are population size, chromosome size, maximum generation count, crossover probabilities, mutation probabilities, number of keeping parents (Elitism). And also the duration of activities, their precedence and the resources should be given before run the application. The parameters are defined as below:

Table 3: The parameters of proposed methods

Parameters	Values
Population Size	50
Chromosome Size	8/12
Max. Generation	1000
Crossover PB	%90
Mutation PB	%20
Elitism	%5

After running genetic algorithm twenty times for the bridge construction problem, it is seen that solution is 108 day at each run, which is the minimum duration of the whole project. The comparisons with the methods that solved this problem are shown in Table 4 and the starting times of activities are shown in Table 5.

Table 4: The comparison of the proposed method for the Bridge Construction problem

Author	Method	Duration
Toklu	Genetic algorithm	108
Haddad and et al.	Honey bee mating opt.	108
Zhao and Ru	Particle swarm opt.	109
Proposed method	Genetic algorithm	108

Table 5: The starting time of activities for the Bridge Construction problem

Author	Method	A1	A2	B1	B2	C1	C2	D1	D2
Toklu	GA	11	41	1	11	26	61	61	91
Haddad	HBMO	16	41	1	11	32	61	66	91
P.Method	GA	11	41	1	11	26	61	61	91

It is seen that the optimal solution can be obtained with proposed method and starting times of the events are the most optimal days to start. Additionally, the running time of the program is less than one second.

In the masonry construction problem, the algorithm is executed twenty times. At each run the optimal solution which is 20 can be obtained. Comparison with the earlier methods is shown in Table 6 and the starting times of the activities are shown in Table 7.

Table 6: The comparison of the proposed method for the Masonry Construction problem

Author	Method	Duration
Hinze	Genetic algorithm	20

Haddad and et al.	Honey bee mating opt.	20
Senouci and Naji	Lagrangian genetic alg.	20
Proposed method	Genetic algorithm	20

Table 7: The starting time of activities for the Masonry Construction problem

Author	A	B	C	D	E	F	G	H	J	K	L	M
Hinze	0	1	3	7	7	13	5	11	9	11	17	19
Haddad	0	1	1	5	5	9	5	3	9	11	17	19
P.Method	0	1	1	5	5	9	5	3	9	11	17	19

With the proposed method the optimal solution is obtained like the previous studies. And starting times are also the best days for each activity. Like the bridge construction, the execution time of the program is less than one second.

5. Conclusion

At first, this two-span bridge construction problem and masonry construction problem can be seen easy, however the constraints about precedence job and limited resources make these problems more complex, so the classical methods cannot solve these problems. The proposed methods can evaluate more than one candidate solution at each time, so they can search all the possible solutions at the same time. Although the genetic algorithms use random approaches at each time, the experiences show that the optimal solution can be achieved at each time. Additionally, the execution times of the proposed methods are less than one second. By this attribution the speed also can be considered as an advantage situation.

6. References

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