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Construction Scheduling via Integration of PERT, GA and GC

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ABSTRACT

In this paper, we propose to integrate Program Evaluation and Review Technique (PERT), Genetic algorithm (GA) and Gantt chart (GC) for scheduling a construction project. Here, earliest start (ES) and earliest finish (EF) times of the activities are considered. Then, the parents, which depend on ES and EF, are selected from the uniform distribution. Crossover and mutation are implemented on the offspring for a better solution. The fitness, which represents the total cost, is computed. As a result, the finishing time and the cost expended for the project are minimized. In conclusion, the efficiency of the approach proposed is shown.

Introduction

Project management involves the way of scheduling, planning, monitoring and controlling of resources, which are workers, skills, time, equipments and facilities, by satisfying a variety of constraints. A good practice in project management assigns the resources to tasks or activities such that the performance of a project is evaluated. The assembly of tasks is performed for a limited duration towards a specific job [1]. On this basis, the typical objectives of project management, which are minimizing the respective cost of completing the project, maximizing the quality of the product and minimizing the duration of the project, are taken into account.

To ensure the project is completed efficiently within a time period, the earliest start (ES) and earliest finish (EF) times for each activity are determined [2]. Here, the ES is the earliest time that an activity can start with the assumption that all of predecessors have been completed whereas the EF is the earliest time that a project should be completed. Consequently, the minimum cost that is expended for running the project can be obtained [3]. In practice, construction managers create a schedule for organizing resources of employees, machines and materials in order to implement a project within the limited available time [4].

In this paper, Program Evaluation and Review Technique (PERT) and Gantt chart (GC) are integrated with Genetic Algorithm (GA) in solving the scheduling problems. In literature, these techniques are used independently or any two of them are integrated to obtain the scheduling solutions. The idea, which integrates PERT, GA and GC, gives the motivation for us to explore the applicable of the approach proposed for a better scheduling solution.

As known in project management community, PERT was established by Booz, Allen and Hamilton in 1958 for the U.S. Navy [5]. The use of PERT is to examine and denote the tasks that are involved in a given activities [6] [7]. By using forward and backward passes ES and EF of each activity for a project are determined. The PERT network is useful to show the connection among the activities in the project [5].

On the other hand, GC is a well-known technique in project management for creating a schedule [8], which is easy to understand and is generally consumed for announcement of on-site at the employee level [9]. GC is usually used in a number of ranges that appears to how natural and effective of the knowledge of demonstrating time-based data streams as quadrilateral bars can be extended along a timeline [10].

The developing of GA is to simulate the genetic evolution process which is survival of the fittest. The growth procedure forecasts the survival and characteristic of the offspring on the root of understand the characteristic of their parents. By nature and based on the fitness of a chromosome, GA is run by three main operators that are selection, crossover and mutation [11]. GA is one of the optimization procedures, which is designed to imitate some of the methods observed in a proper development [12].

Problem Statement

In construction industry, completing the project in the expected time is a crucial task. The completion of a project gives an economical perspective to satisfy the request of the customers.

In contrast, the failure of a scheduling is an unwanted tragedy for companies since the extra time is spent and the resource is wasted. Due to these reasons, managers need a better technique to develop a good schedule of the project and to ensure their projects can be finished in the desired time period.

Furthermore, the manager has to decide how long each activity will be taken and compute how many resources, including workers and materials, will be needed at each stage of the project [5]. Since scheduling is the bottom atomic partition of the project, which cannot be sectioned, the activities of the project that are frequently estimated in terms of resource requirements, budget and duration are connected dependently [13].

The existing tools of project management such as PERT, GC, Critical Path Method (CPM), and Work Breakdown Structure (WBS) are the tools that are used to monitor the project. In fact, PERT and GC cannot cope the back-and-forth

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altercation of information that usually happens in product development projects [14] [15]. This issue becomes our aim to integrate PERT, GC and GA in providing an efficient scheduling solution as well as completing the project in a reasonable time period. It is noticed that the period of the project would be shorten. So that, the total cost of the project is minimized.

Integration of PERT with Genetic Algorithm and Gantt chart

In PERT, both of ES and EF of each activity in a project are considered. The duration for each activity is calculated from

$$\text{Duration} = \text{EF} - \text{ES} \qquad (1)$$

and the cumulative duration is the total time spent for completing the project.

Here, the aim is to reduce the total time and to minimize the cost of running the project. Thus, a method that is based on the GA is proposed to obtain the respective duration of each activity in scheduling the project. The operators of GA are performed as follow.

For the selection, the genes of the parents are produced from the uniform distribution given by

$$a + r \times (b-a) \qquad (2)$$

where a is the ES, b is the EF and r is the random number. The values of a and b are real data taken from the project of a construction company. The random number r is generated by using the command *rand* () from the Excel spreadsheet.

For crossover, one-point crossover is used. Initially, a single crossover point is selected. The point from the beginning of the chromosome to the selected crossover point is copied from the first parent and the rest chromosome is copied from the second parent. In such way, two offspring are produced.

For mutation, one point of the chromosome in the respective offspring is chosen randomly. By using Equation 2, a random number is generated and the value of the selected point is updated. This way is done for both offspring.

When the operators of crossover and mutation are completed, the last point of each offspring is observed. This point gives the total time spent for completing a project. Hence, the minimum value of these two points between the first and second offspring is taken. The offspring with the minimum point is the desired schedule and the point of the offspring represents the earlier finish time for each activity. Further from this, the new EF can be assigned, while the ES remains the same. The duration for each activity is then calculated from Equation 1 before a new Gantt chart is plotted.

The fitness function is the total cost expensed for completing a project, which is given by

$$\text{total cost of project} \times \frac{\text{new duration of project}}{\text{original time of project}} \qquad (3)$$

From the discussion above, the computation procedure is summarized as follows:

Step 1: Generate the genes of the parents from Equation 2. Set $i = 0$.

Step 2: Produce the offspring by using one-point crossover.

Step 3: Choose a point from the offspring randomly, and update the value of the point by using Equation 2.

Step 4: Determine the total time of completing the project from the last point of the offspring. Then, calculate the fitness value from Equation 3. Set $i = i + 1$, repeat from Step 1 to Step 4 until the generation of $i = N$ is satisfied.

Case Study

In this case study, the project of building bounding walls at four different venues, which are *Nibong* Road 4, *Nibong* Road 3, *Tengar* Road and *Nibong* Road 5, is considered. The project is located at Pasir Gudang, Johor. The project is run from Monday to Saturday, the working hour is from 8.00 am until 5.00 pm, and the project is off on Sunday. The project has 11 activities for each of *Nibong* Road 4, *Nibong* Road 3 and *Tengar* Road, and three activities at *Nibong* Road 5.

In this project, each activity is linked together and they must be finished accordingly. Contractor cannot skip any activities to finish this project. This project starts on 2/12/2013 and finishes on 26/3/2014. The finishing time of the project is 99 days. Total cost for this project is RM1, 300, 000. Table 3 shows the data of the project.

The respective ES and EF are shown in Table 4, where the duration for each activity is calculated from Equation 2.

The expected completion time for this project is 97 days, which is 2 days earlier than the origin completion time. Gantt chart for the project is then shown in Figure 1.

Figure 1. PERT integrated with Gantt chart

Result and Discussion

Table 5 shows the generation of the data by using the approach proposed, where crossover happened at 25th position and mutation occurred at 35th position of the chromosome of the offspring, and P1, P2, Of1, Of2, M1 and M2 are, respectively, represent Parent 1, Parent 2, Offspring 1, Offspring 2, Mutation 1, Mutation 2.

From the columns of the mutations, 93-day is the most appropriate day to finish the project in a minimum time period. In Table 6, the new calculation of EF is shown; however, ES remains the same. Figure 2 shows the new Gantt chart for the new duration of the project schedule after refining by GA operators.

Table 3. Data of the Project

Task	Activity	Duration (days)	Start	Finish
1	Preliminaries	99	Mon 12/2/13	Sat 3/26/14
	***NIBONG* ROAD 4**			
2	Excavation	18	Mon 12/9/13	Sat 12/28/13
3	Lean concrete	17	Wed 12/11/13	Mon 12/30/13
4	Base formwork	17	Thu 12/12/13	Tue 12/31/13
5	Reinforcement	17	Fri 12/13/13	Wed 1/1/14
6	Concrete	17	Mon 12/16/13	Fri 1/3/14
7	Formwork wall	26	Mon 12/23/13	Tue 1/21/14
8	Reinforcement wall	24	Fri 12/27/13	Thu 1/23/14
9	Concrete wall	23	Mon 12/30/13	Fri 1/24/14
10	Reinforcement column	16	Mon 1/27/14	Thu 2/13/14
11	Formwork column	17	Wed 1/29/14	Mon 2/17/14
12	Concrete column	14	Mon 2/3/14	Tue 2/18/14
	***NIBONG* ROAD 3**			
13	Excavation	18	Mon 12/30/13	Sat 1/18/14
14	Lean concrete	17	Tue 12/31/13	Sat 1/18/14
15	Base formwork	17	Wed 1/1/14	Mon 1/20/14
16	Reinforcement	17	Thu 1/2/14	Tue 1/21/14
17	Concrete	14	Mon 1/7/14	Wed 1/22/14
18	Formwork wall	24	Fri 1/24/14	Thu 2/20/14
19	Reinforcement wall	23	Mon 1/27/14	Fri 2/21/14
20	Concrete wall	12	Tue 2/10/14	Sat 2/22/14
21	Reinforcement column	11	Tue 2/11/14	Sat 2/22/14
22	Formwork column	10	Fri 2/14/14	Tue 2/25/14
23	Concrete column	10	Mon 2/17/14	Thu 2/27/14
	***TENGAR* ROAD**			
24	Excavation	14	Mon 1/20/14	Tue 2/4/14
25	Lean concrete	14	Tue 1/21/14	Wed 2/5/14
26	Base formwork	15	Wed 1/22/14	Fri 2/7/14
27	Reinforcement	16	Thu 1/23/14	Mon 2/10/14
28	Concrete	14	Mon 1/27/14	Tue 2/11/14
29	Formwork wall	16	Mon 2/17/14	Thu 3/6/14
30	Reinforcement wall	17	Thu 2/20/14	Tue 3/11/14
31	Concrete wall	13	Tue 2/25/14	Tue 3/11/14
32	Reinforcement column	11	Fri 2/28/14	Wed 3/12/14
33	Formwork column	10	Mon 3/3/14	Thu 3/13/14
34	Concrete column	9	Wed 3/5/14	Fri 3/14/14
	***NIBONG* ROAD 5**			
35	Reinforcement column	11	Wed 3/12/14	Mon 3/24/14
36	Formwork column	11	Thu 3/13/14	Tue 3/25/14
37	Concrete column	5	Fri 3/21/14	Wed 3/26/14

Table 4. Calculation of ES and EF

Activity	ES	EF	Duration
***NIBONG* ROAD 4**			
Excavation	0	18	18
Lean concrete	2	19	17
Base formwork	3	20	17
Reinforcement	4	21	17
Concrete	6	23	17
Formwork wall	12	38	26
Reinforcement wall	16	40	24
Concrete wall	18	41	23
Reinforcement column	42	58	16
Formwork column	44	61	17
Concrete column	48	62	14
***NIBONG* ROAD 3**			
Excavation	19	37	18
Lean concrete	20	37	17
Base formwork	21	38	17
Reinforcement	22	39	17
Concrete	26	40	14
Formwork wall	41	65	24
Reinforcement wall	43	66	23
Concrete wall	55	67	12
Reinforcement column	56	67	11

Formwork column	59	69	10
Concrete column	61	71	10
***TENGAR* ROAD**			
Excavation	38	52	14
Lean concrete	39	53	14
Base formwork	40	55	15
Reinforcement	41	57	16
Concrete	44	58	14
Formwork wall	62	78	16
Reinforcement wall	65	82	17
Concrete wall	69	82	13
Reinforcement column	72	83	11
Formwork column	74	84	10
Concrete column	76	85	9
NIBONG* ROAD *5			
Reinforcement column	83	94	11
Formwork column	84	95	11
Concrete column	92	97	5

Table 5. Data of the Generation

P1	P2	Of1	Of2	M1	M2
15	16	15	16	15	16
4	18	4	18	4	18
14	5	14	5	14	5
9	13	9	13	9	13
22	22	22	22	22	22
16	37	16	37	16	37
39	28	39	28	39	28
36	21	36	21	36	21
49	57	49	57	49	57
57	60	57	60	57	60
57	48	57	48	57	48
34	36	34	36	34	36
32	33	32	33	32	33
34	28	34	28	34	28
33	25	33	25	33	25
36	26	36	26	36	26
48	42	48	42	48	42
45	62	45	62	45	62
63	59	63	59	63	59
66	56	66	56	66	56
63	63	63	63	63	63
69	69	69	69	69	69
41	45	41	45	41	45
45	48	45	48	45	48
51	51	51	51	51	51
45	52	52	45	52	45
53	46	46	53	46	53
64	70	70	64	70	64
81	71	71	81	71	81
77	72	72	77	72	77
80	75	75	80	75	80
79	81	81	79	81	79
84	85	85	84	85	84
89	85	85	89	85	89
86	87	87	86	87	87
96	93	93	96	93	96

Table 6. The New Duration

Earlier Start Time (ES)	Earlier Finish Time (EF)	Duration (EF – ES)
0	13	13
2	13	11
3	5	2
4	10	6
6	19	13
12	15	3
16	29	13
18	40	22
42	47	5
44	59	15
48	60	12
19	29	10
20	30	10
21	29	8
22	31	9
26	39	13
41	61	20
43	57	14
55	66	11
56	58	2
59	60	1
61	68	7
38	49	11
39	50	11
40	46	6
41	57	16
44	49	5
62	66	4
65	80	15
69	76	7
72	74	2
74	79	5
76	84	8
83	93	10
84	92	8
92	93	1

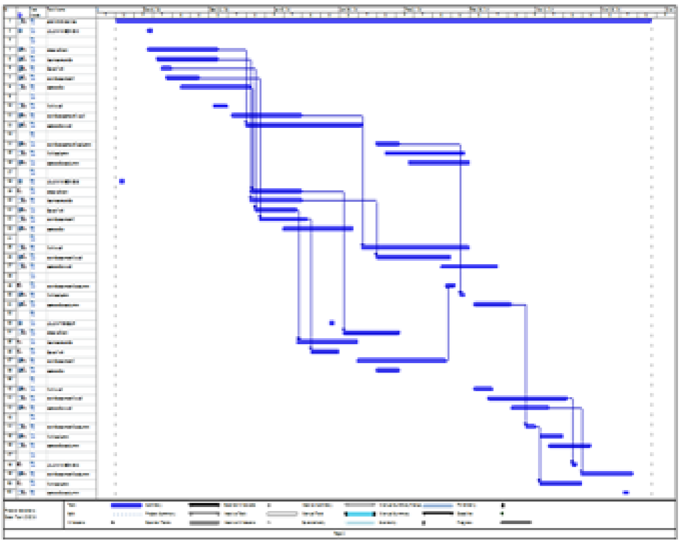

Figure 2. The New Gantt chart

Notice that the updated duration of activities is less than the origin data when GA is applied. Additional, the total cost spent for the project is minimized to RM 1,221,212.12, where the cost of RM 78,787.88 is saved.

Conclusion

An integration of PERT, GA and GC for project scheduling was developed in this paper. By using this approach proposed, ES, EF and the corresponding duration of each activity of the project are calculated. The operators of GA are then applied to refine the scheduling solution, where the values of EF of the project are revised. For the refined solution, Gantt chart is made in order to visualize the effective of the project schedule. In conclusion, the approach proposed is applicable for scheduling the project and its efficiency is proven to be useful for project managers.

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