

A Crew Model using GAIIPDM in Repetitive Projects



Jeeno Mathew, Brijesh Paul

Abstract: Several indistinguishable or comparative tasks/works in a project are generally alluded to as repetitive projects. A project have group of tasks which is repetitive in nature in all over the project or a similar plan in different positions are commonly known as repetitive project. In repetitive project businesses, distinctive crew choices are accessible for each task, and selecting the best choice to a task is a noteworthy test for administrators of a project. Since acquiring optimum results is found computationally escalated for this type of problems, a modified Genetic Algorithm based technique is developed to schedule projects to satisfy different goals like minimizing total task time and the total expenditure of the project, with the constraints of precedence connections between different tasks, precedence connections between different sites and the due time within which different tasks to be finished. The performance of the proposed method is compared with solutions created using existing algorithms like simple GA and ABC. Exact solutions generated by solving the developed mathematical model is utilized for validating the solutions acquired by modified GA. The computational outcomes demonstrate that the proposed GAIIPDM methodology performs significantly well in terms of quality of solutions.

Keywords: ABC, GA, GAIIPDM, Repetitive Projects.

I. INTRODUCTION

Present day project companies are facing tight competition in terms of quality, cost and delivery times. Satisfying the customer demands and maintenance of profit levels are some of the major challenges faced by these companies and hence, proper scheduling plays an important role in this regard. Most of the projects are repetitive in nature. So project managers are keen to find out the finest choice for scheduling the repetitive projects in a short span.

Selinger [1] and Russell *et al.* [3] developed two distinctive scheduling strategies to satisfy the goal of minimizing the total project task time in which the first author pursued to maintain the work continuity of crews while the second one enabled the crew work interruptions. Mosenhli *et al.* [2] and Hegazy *et al.* [4] also prepared two

different classes of accessible methodologies for minimizing the total expenditure of the project in which crew work continuity and crew work interruptions are respectively applied as in the previous case. These two techniques are designed for optimizing just a single objective at any given moment.

In many situations, repetitive projects will involve a large number of decision parameters and nonlinear limitations. This prompted many researchers to develop heuristic techniques for planning the projects which is repetitive. Khaled Nassar [6] built a technique to limit the total project task time and the break of days so as to dole out the crew to repetitive tasks by using genetic algorithm. In order to minimize project task time, total project expenditure, or both of them, Long and Ario Ohsato [7] proposed a method with the constraints of precedence connections among different project tasks and constraints of resource work continuity. A.Senouci and Hassan R.AIDesham [8] tackled a similar issue utilizing the pareto optimality guideline. Fatma A. Agrama [10] presented a model where the project managers need to create ideal/close ideal building plans to fulfill the goals like minimizing of total project task time, crew work interruption and the number of synchronized groups in repetitive project works. Fatma A. Agrama [9] proposed another model to help the arrangement of a non-identical multi-story construction in which a two variable multi objective optimization is considered. The first model is dependent on an ideal balance achieved between the goals of complete task time of the project and the number of interruption days whereas the second model is based on cost parameters such as a compromise between the complete expenditure of the project and the complete penalty cost corresponding to the crew work intermissions.

R.Y Huang *et al.* [11] developed a technique to maximize the NPV in a repetitive project industry where the best possible work arrangement between workgroups is accommodating and keeping up work progression of resources. S.L Fan *et al.* [12] also built up a model similar to the previous one where the goal is to minimize the total project expenditure Jeeno Mathew *et al.* [21] developed a genetic algorithm based methodology for scheduling repetitive projects in which penalty cost is also considered. An optimization software (OSS) was developed by Remon Fayek Aziz [13] for maximizing the NPV of a project.

Though we could see distinctive models discussing exact and heuristic procedures for scheduling repetitive project work problems, most of the discussions are only on a single objectives like minimization of the inactive crew hour,

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maximization of the NPV or maximization of learning effects by work continuity in a repetitive project industry. There are only exceptionally less number of articles which deals with optimization of multiple objectives.

In multi objective optimization, the decision maker has to react to multiple objectives. For the most part, all goals cannot at the same time reach at their ideal levels because all the objectives are conflicting in nature. The delaying of tasks due to various reasons is another real challenge in the project industries which influence the clients. In this situation, a fine is being charged for each slack day of every task in all sites to avoid the monetary misfortune of the clients. But there are only few articles that discuss this kind of problems. So to build up a technique by considering the penalty cost corresponding to the dragging of the task is extremely significant in the case of scheduling repetitive projects in a multi objective optimization problem.

II. MODEL

This paper considers an organization does the similar type of jobs in different sites of the project (e.g.- Pipeline networks, Housing projects etc.). A project is split up into different project sites and each site consist of several tasks and the particular tasks are repeated in different project sites (Vanhoucke M. [14]). In this model, we consider an organization is having ‘S’ distinctive sites in which work is going on and each site is divided into ‘N’ different tasks. Every site is demonstrated by a network, where a set of ‘N’ tasks have priority order relationships and these connections are continuing in ‘S’ sites. Normally a resource group is allocated to the individual task of every site. The resource group performs the similar task sequentially and persistently in different project sites (Harris R.B *et al.* [15]). Various resource alternatives are available for each task and each group has an independent task time and expenditure per unit amount of work. To carry out the action, the selected resource moves along various project destinations. Finding out an optimal schedule to minimize the different objectives like the total project task time, total project expenditure and both of them are considering in this study and also it involves a circumstance where if a task is deferred, the organization should pay a penalty cost to the client relating to that movement for each dragging days from the due date.

A mathematical model is proposed by Jeeno Mathew *et al.* [21] to solve the problem for satisfying the objectives like minimizing total project task time, total expenditure of the project and minimize both expenditure and task time on a repetitive project scheduling problem with the constraints of precedence connectivity among different tasks and precedence connectivity among different sites. In addition to the above mentioned objectives, the penalty cost corresponding to each task in every lagging project site is considered.

Nomenclature

- i* Task
- j* Project site
- k* Crew
- t_{ki} Task time for unit amount of work of k^{th} crew of task *i*

- T_{ij} Task time of task *i* in site *j*
- T_{tj} Task time of precedence task *t* in site *j*
- lag_{tj} Lag time of task *t* in site *j*
- ST_{ij} Begin time of task *i* in site *j*
- LT_{ij} Delay time of task *i* in site *j*
- DD_{ij} Due date of task *i* in site *j*
- FT_{ij} Finish time of task *i* in site *j*
- PT Total project task time for the project
- c_{ki} Direct expenditure for unit amount of work of k^{th} crew of task *i*
- C_{ij} Direct expenditure for task *i* in site *j*.
- p_i Penalty expenditure for task *i* per day
- ic Indirect expenditure per day.
- C_D Total direct expenditure.
- C_p Total penalty expenditure.
- C_I Total indirect expenditure.
- C_o Total initial expenditure.
- C Sum of direct, indirect and penalty expenditure.
- qw_{ij} Work quantity of task *i* in site *j*.
- wt_t Weightage given to the task time.
- wt_c Weightage given to the expenditure.

Objectives

Minimize total project task time

$$Z_1 = \text{Min}\{\text{Max}\sum_{i=1}^N \sum_{j=1}^S (ST_{ij} + T_{ij})\} \quad (1)$$

Minimize total project expenditure

$$C = (C_D + C_p + C_I + C_o) \quad (2)$$

$$Z_2 = \text{Min}((\sum_{i=1}^N \sum_{j=1}^S [(C_{ij}) + (LT_{ij} \times p_i)]) + (ic \times PT) + C_o) \quad (3)$$

Minimize the cumulative impact of both total project task time and total project expenditure

$$TE = \sqrt{((wt_t \left(\frac{PT - Z_1}{Z_1} \right)^2)) + (wt_c \left(\frac{C - Z_2}{Z_2} \right)^2)} \quad (4)$$

In equation 4, the objective *TE* is found out using decision maker’s predetermined weights (wt_t , wt_c) that consider the overall significance of total project task time(*PT*) and total expenditure(*C*) respectively. The weightage assigned to the task time and expenditure (wt_t , wt_c) are chosen independently, in the range [0.0, 1.0] by managers, and they ought to fulfil the condition ($wt_t + wt_c = 1.0$). The trade-off solutions obtained from equation 4, *PT* and *C* represent the total project task time and the total expenditure of the project. Z_1 and Z_2 represent the absolute solutions corresponding to the single objectives like minimize the total project task time and the total expenditure and it is acquired separately by solving equations 1 and 2 with respect to its constraints.



The objective function match up with equation 4 is a numeric technique which calculates the most limited separation among the solution corresponding to the selected schedule (C, PT) and the individual optimum solutions (Z_1, Z_2).

So this equation searches the beneficial trade-off arrangement that would look for the lowest comparative variation from the perfect arrangement. (Tabucanon M.T. [16]).

Constraints

Task time to complete task i of k^{th} crew in project site j

$$T_{ij} = t_{ki} \times qw_{ij} \quad (4)$$

Direct expenditure for task i of k^{th} crew in project site j

$$C_{ij} = c_{ki} \times qw_{ij} \quad (5)$$

Delay time of task i in site j

$$LT_{ij} = \text{Max}(0, FT_{ij} - DD_{ij}) \quad (6)$$

Precedence relationship among different tasks

$$ST_{t_j} + T_{t_j} + lag_{t_j} \leq ST_{t_i} \quad (7)$$

Relationships among tasks of different sites

$$ST_{ij} + T_{ij} \leq ST_{i(j+1)} \quad (8)$$

III. METHODOLOGY

The real test for the project decision makers in this case is to choose an ideal crew scheduling choice from accessible search space. The possible options make a huge search space where every arrangement speaks to a suitable alternative for finishing the project. A. Senouci *et al.* [8] explains about an example in which 95 trillion (i.e 5^{20}) feasible choices are possible when a project comprising of 20 different tasks and for every task 5 distinctive crew alternatives are available. So here an endeavor is made to build up a heuristic based arrangement procedure for this sort of issues, since the computational complexity is too high for getting definite arrangements in repetitive project scheduling. A modified Genetic Algorithm based technique is developed to solve the problem under study and the mentioned method is compared with existing methodologies like Genetic Algorithm [18] and Artificial Bee Colony algorithm [19] are discussing in this paper. Though complex, exact solutions are also obtained for smaller size problems, by solving the developed mathematical model using a solver and these solutions are used to validate the proposed methodology.

IV. GAIIPDM

Here we propose a modified GA where Genetic Algorithm with *Initially Improved Population and Dynamic Mutation* (GAIIPDM) is applied.

In this work, task time for the unit amount of work is taken as decision parameters. A chromosome in a population is made up of different genes which will be the decision variables. The initial population of GAIIPDM is randomly produced. The chromosome representation of GAIIPDM is shown in fig1.

t_1	t_2	t_3	t_4	t_5	t_N
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Fig 1. Chromosome representation of GAIIPDM.

Each chromosome contains N decision parameters and speaks to a potential arrangement compares to a generated plan. The separation among the maximum task time for the unit work quantity of the i^{th} task of k^{th} crew (t_{ik}^{max}) and the minimum task time for the unit work quantity of the i^{th} task of k^{th} crew (t_{ik}^{min}) of considerable number of crews in a task is applied to find out the chromosome size. If the decision parameters are in a range of $[t_{ik}^{\text{min}}, t_{ik}^{\text{max}}]$, then the size of the chromosome can be decided from the connection exhibited in the following equation where n represents the number of bits in a decision parameter.

$$2^{n-1} \leq (t_{ik}^{\text{max}} - t_{ik}^{\text{min}}) \times 10^a \leq 2^n - 1 \quad (9)$$

Here 'a' denotes the needed accuracy which indicate the scale of decision parameter is segmented into at least $(t_{ik}^{\text{max}} - t_{ik}^{\text{min}}) \times 10^a$ equal size ranges (Leu S.S *et al.* [17]). Then find out the crew choice according to each task and select corresponding t_{ik} and c_{ik} of each activity. A task in which Q crew alternatives are available, at that point a specific group will be chosen by the relation as shown below.

$$P(i) = R(i) \times [Q / (2^n - 1)] \quad (10)$$

Where $R(i)$ is the decimal value corresponding to the binary substring of task i and $P(i)$ is the crew choice will be select. If $(Q-1) \leq P(i) \leq Q$, then the decision maker will be opt for the choice Q .

The fitness of each chromosome in the population is determined by the assistance of a scheduling algorithm. The scheduling algorithm is designed to find out the total project task time and total project expenditure incurred by using a particular set of project crews.

After the fitness evaluation of the initial population, each chromosome generates a new chromosome using equation 11 and a greedy selection process is used to compare the fitness of both chromosomes and select the fittest one (18). It will repeat on every chromosomes of the initial population.

$$V_{pi} = X_{pi} + \varphi_{pi} (X_{pi} - X_{ri}) \quad (11)$$

Here V_{pi} is a new feasible solution modified from its previous solution X_{pi} in which 'p' and 'r' represent chromosomes in population, 'i' represents the activity. Here 'r' and 'i' are randomly chosen indexes. Although r is determined randomly, it has to be different from 'p' the present chromosome. φ_{pi} is a random number between [-1,1]. Then check the fitness of the new chromosome originated from the existing one and do the procedures as mentioned above.

By the use of GA operators [20], a new population is set up in the next generation and after that determine the ideal plausible schedule from different generations. Roulette wheel selection technique is followed for selection of chromosomes. As discussed earlier, we consider three different objective functions; minimize total project task time, minimize total project expenditure and a combination of expenditure and task time.



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Therefore, the fitness of the chromosomes will be project task time, project expenditure, and a cumulative impact of both task time and expenditure respectively. The single point

cross over operation and the bit flip mutation are used as cross over and mutation operators. The detailed parameter setting for these operators are explained in the next section.

Table- I: Input data for quantity of work of problem1

Work Quantity																		
	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18
S1	4.5	30	5	2	0.25	10	3	1	2	0.5	4	3	1.5	4	6	2	1	6
S2	1	40	10	4	0.5	25	2	2	2	1	4	6	1.5	2	6	2	1	6
S3	4.5	35	0	2	0.25	15	3	1.5	2	0.5	6	0	1.5	1	6	2	1	6
S4	2.5	0	10	3	0.5	20	4	1	2	0.5	2	7	1.5	2	6	2	1	6
S5	5.5	30	5	4	0.25	15	4	2.5	2	0.5	0	2	1.5	4	6	2	1	6

Table- II: Input data for expenditure per unit amount of work of problem 1

Expenditure for unit amount of work																		
Crew Choice	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18
Choice1	130	30	180	440	2164	48	255	1560	235	620	540	326	390	390	265	120	1460	227
Choice2	70	13	160	380	1825	42	143	1300	160	70	450	242	150	300	214	88	680	193
Choice3	50	-	135	340	1434	30	66	1000	135	-	400	110	-	250	170	40	290	167
Choice4	-	-	110	320	991	12	-	900	85	-	350	-	-	200	137	-	-	148
Choice5	-	-	-	300	496	-	-	660	60	-	-	-	-	-	102	-	-	92

Table- III: Input data for task time per unit amount of work of problem 1.

Task time for unit amount of work																		
Crew Choice	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18
Choice1	1	0.1	0.4	1	4	0.2	1	2	0.5	2	0.5	1	2	1	0.5	0.5	1	0.5
Choice2	4	0.4	0.6	2	5	0.3	3	3	0.8	4	0.85	3	5	2	0.9	0.7	3	1
Choice3	5	-	0.8	4	6	0.5	4	4	0.9	-	1	5	-	3	1.2	1	4	1.3
Choice4	-	-	1	5	7	0.8	-	5	1.1	-	1.2	-	-	4	1.4	-	-	1.5
Choice5	-	-	0	6	8	-	-	6	1.2	-	-	-	-	-	1.6	-	-	2

The performance of GAIIPDM is by and large dependent on the setting of the GA parameters [20]. It is particularly vital to set these parameters precisely so as to obtain high quality solutions. The major parameters impacting the performance of GAIIPDM are population size, the number of iterations, cross over rate, mutation rate etc. The population size is fixed as four times the number of decision variables. Based on a pilot study the cross over rate was fixed as 0.8. The dynamic mutation is applied in GAIIPDM where up to hundred generations, mutation rate is fixed as 0.06, then between 100 to 250, 250 to 500, 500 to 1000 and more than 1000 generations mutation rate becomes 0.05, 0.03, 0.02 and 0.01 respectively.

V. COMPUTATIONAL STUDY

In this paper the proposed GAIIPDM algorithm is compared with the existing methods such as simple GA and ABC algorithm. For effective evaluation, all related algorithms were programmed in the MATLAB (R2014a) platform and the test problem is solved by simple GA, ABC

and GAIIPDM. For the proposed algorithm validation and comparison, a repetitive project scheduling problem with multiple crew option in each activity is considered. A project consists of 18 tasks in a project site and five repetitive sites in which work is going on with the input data taken from Jeeno Mathew *et al.* [21] as shown in Table I, Table II and Table III where “N1, N2, N3...” are different tasks, “S1, S2, S3...” represents different sites. 5 different crew choices are possible for 18 tasks and it is represented as “choice1, choice 2...” and its expenditure and task time for the unit amount of work are shown in table II and table III respectively. A specific due date to complete the work is given for every task in each project site. If a task is not completed its corresponding due date, then a penalty cost relating to each lagging day is added to the total expenditure of the project. The penalty cost with respect to each task is captured randomly from a rectangular distribution U [35,400].

VI. CONCLUSION

A strategy for planning repetitive projects with the goal of limiting total task time of the project, total expenditure of the project and two of them simultaneously are exhibits in this paper. The present model in which if a specific task isn't finished at the delivery time in a site, at that point, a fine amount corresponding to the delay period is put together to the total expenditure of the project. The technique considers the time limit in which the activity should be finished for each task in every site, precedence connections among different project sites and precedence connections among different tasks. The mentioned technique is applied to a test problem from literature and the solutions obtained are validated using exact solutions obtained by solving the mathematical model using CPLEX solver. A comparative study of the generated solutions is also conducted with the solutions generated using existing algorithms like GA and ABC algorithm.

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