RESOURCE-CONSTRAINED PROJECT SCHEDULING PROBLEM: AN OVERVIEW

S.V.Kamble[1], V.C. Sakhare[2], Dr.P.D.Gangawane[3]
[1,2,3]Assistant Professor in Information Technology Department
DKTE'S Society's Textile & Engineering Institute, Ichalkaranji, Dist:Kolhapur, Maharashtra
Pin:416115

***Abstract:* Project scheduling with limited resources is a challenging management problem in operational research that is of immense importance to both practitioners and researchers.Thus, the successful implementation of project scheduling is a key factor to projects' success. Due to its complexity and challenging nature, scheduling has become one of the most famous research topics. Therefore, the project scheduling issue has been significantly evaluated over time and has been developed from various aspects.In this paper we focus the topics related to Resource-Constrained Project Scheduling Problem (RCPSP) are reviewed. This paper reviews different optimization algorithms techniques that are used for RCPS to achieves the minimum project duration problem such as Genetic Algorithm (GA), Particle Swarm optimization (PSO), Tabu Search (TS), Simulated annealing.**
***Keywords:* Genetic algorithm (GA), Project Scheduling, Simulated Annealing (SA)**

I. INTRODUCTION

The project scheduling problem (PSP) is one of the most challenging problems in the operations research (OR) field; In PSP problem in which the most famous and heavily researched problem type is the resource-constrained project scheduling problem [2]. PSP, especially RCPSP, has been considered as NP-Hard in the strong sense [7][2], and accordingly most researches within the last two decades concentrated on heuristics and met heuristics for solving different PSP types. RCPSP became a very hotspot for researchers either in operation research or in scheduling field. It involves the determination of each activity start time which achieves the minimum project duration without violating any of the precedence or resource constraints [3].

A resource-constrained project scheduling problem (RCPSP) consist of allow limited resources availability as per resource requests and furnish the activities of known durations, linked with precedence relation. A resource-constrained project scheduling problem mostly used for finding schedule of minimal duration by assigning a start time to each activity such that the precedence relations and the resource availabilities are respected. Important thing of project management is scheduling, which has been turned into a difficult task due to resource constraints along with precedence relationships. As a result, the problem of project scheduling is considered by researchers as one of the most commonly used and fundamental issues [1].

Decomposition of real RCPS project depends upon size and complexity of the problem it may be included important factor such as (A) the analysis includes multiple and conflicting objectives (B) The problem size grows exponentially with the number of project activities, resource types, and alternative activity execution modes, and (C) the number of alternative resource engagements in each activity may be large [4].

II. LITERATURE REVIEW

So far, Existing research has produced a variety of methods and algorithms for the resource-constrained project scheduling problem. They can be classified as exact methods (linear/integer or dynamic programming), heuristic algorithms, and meta-heuristic or evolutionary algorithms. The RCPSP problem attains a significant size as the number of project activities, resource types, and alternative activity execution modes increase. For this reason, the focus of most recent studies has been directed to meta heuristic or evolutionary algorithms, primarily genetic algorithms (GA) [4].

Hartmann, S. [8] author has implies Genetic Algorithm (GA) method for solving the classical resource-constrained project scheduling problem. They propose a new GA approach to solve this problem. They employs a new representation for solutions that is an activity list with two additional genes. The first, called serial-parallel scheduling generation scheme gene (S/P gene), determines which of the two decoding procedures is used to computer a schedule for the activity list. The second, called forward-backward gene (F/B gene).

Alcaraz, J. & Maroto, C.[9] author has propose a new representation for the solutions, based on the standard activity list representation and develop new crossover techniques with good performance in a wide sample of projects.

Valls, V., Ballestin, F., & Quintanilla, M.S. [10], authors has propose a Hybrid Genetic Algorithm (HGA) for the Resource-Constrained Project Scheduling Problem (RCPSP). HGA introduces several changes in the GA paradigm: a crossover operator specific for the RCPSP, a local improvement operator that is applied to all generated schedules, a new way to select the parents to be combined.

Chen, R.M. [11], author has proposes a novel JPSO scheme with designed mechanisms to solve the resource-constrained project scheduling problem (RCPSP). They suggested JPSO also involves the LFT heuristic, double justification (DJ), mapping, forward and backward particle swarms for forward–backward improvement (FBI), and adjusting communication topology by gbest ratio (GR).

Abdolvahab Raeisi Dana[6], author has proposed an optimization algorithm for resolution of the problem project scheduling with limited resources is examined. This optimization algorithm includes a combination of PSO algorithm and gravitational search algorithm.

Lo, S. T., Chen, R. M., Huang [13], author has presents and evaluates a modified ant colony optimization (ACO) approach for the precedence and resource-constrained multiprocessor scheduling problems. A modified ant colony system is proposed to solve the scheduling problems. A two-dimensional matrix is has proposed for study of assigning jobs on processors, and it has a time-dependency relation structure.

Thomas, P. R., & Salhi, S.[14], author has implies tabu search to solve the resource constrained project scheduling problem. An appropriate tabu search is designed for this approach uses well defined move strategies and a structured neighborhood, defines appropriate tabu status and tenure and takes account of objective function approximation to speed up the search process.

Kirkpatrick et al. [15], author has proposed the simulated annealing (SA) was presented by as an optimization method which mimics the behavior of a system in thermodynamic equilibrium at certain temperature.

III. PROBLEM FORMULATION

Resource-Constrained Project Scheduling Problem (RCPSP)

The RCPSP can be defined as a combinatorial optimization problem, it is defined by solution space X, which is discrete or which can be reduced to a discrete set, and by a subset of feasible solutions $Y \subseteq X$ associated with an objective function $f : Y \rightarrow R$. A combinatorial optimization problem aims at finding a feasible solution $y \in Y$ such that $f(y)$ is minimized or maximized.

Activities in the project scheduling are identified by a set $V = \{A_0,...,A_{n+1}\}$. Activity A_0 represents by convention the start of the schedule and activity A_{n+1} symmetrically represents the end of the schedule.

Durations are represented duration of activity A_i.

Precedence relations are given by E, a set of pairs such that $(A_i, A_j) \in E$ means that activity A_i precedes activity A_j.

Renewable resources are formalized by set $R = \{R_1,...,R_q\}$.

Availabilities of resources are represented by a vector B in N^q such that B_k denotes the availability of R_k

Availabilitiesof resources are represented by a vector B in N^qsuch that $B_k$denotes the availability of R_k. In particular, a resource $R_k$such that $R_k= 1$ is called a unary or disjunctive resource. Otherwise, as a resource may process several activities at a time, it is called a cumulative resource.

A scheduleis a point S in R^{n+2} such that $S_i$represents the start time of activity A_i. $C_i$denotes the completion time of activity A_i, with $C_i= S_i+p_i$. $S_0$is a reference point for the start of the project, assume that $S_0=0$.

Objective Function:

The objective of the RCPSP is to find precedence and resource feasible completion times for all activities such that the makespan of the project is minimized.

$S_j - S_i \geq p_i \; \forall (A_i,A_j) \in E$ ----------- (1.1)

Solution S is feasible if it is compatible with the precedence constraints (1.1)

Classification of RCPS Problem:

A. Resource constraint:

The need to resources, only in the form of renewable resources and assuming that they have a full capacity in each period and a fixed amount of the resource is occupied during the implementation of the activity, has been accessed by RCPS problem.

B. Renewable resources:

It means that resource constraints have been periodic and when the activities are initiated, a specific amount of this type of resources is exploited and returned at the end of the process.

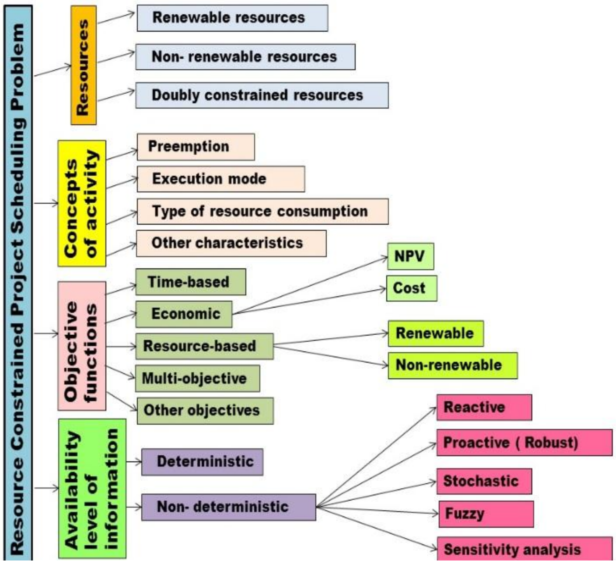

Fig. 1. Classification of resource-constrained project scheduling problems [1]

IV. EVOLUTIONARY ALGORITHM FOR RCPS

A] GA for RCPS Problem:

Genetic algorithms (GA) technique is one of the most popular meta-heuristics in the field of scheduling. Holland [16] developed this method as a simplification of evolutionary processes occurring in nature. GA is basically an iterative evolutionary method through which the overall quality of solutions (or genomes) population is improved from one generation to the next through three nature resembled mechanisms: selection, crossover, and mutation [17][18].

GA considers a population of solutions instead of one solution. After creating the initial population, new solutions are generated by mating two existing solutions (Crossover) or by altering an existing one (Mutation). The fittest of these survive and move on to the next generation by the means of a selection process while the rest are discarded. Fitness value measures the quality of solution, depending on the objective function of the problem to be solved [17][18].

Pseudo code of basic Genetic Algorithm

Begin Genetic Algorithm

Generate initial population with random parents

Evaluate each parent in the population

For (j =1 to NGEN)
Apply crossover with probability Pc on parents
Apply mutation with probability Pm on child
Add children to the current population
Retain best parents
Evaluate the new generation
End For
End

One of the biggest advantages of Hartmann's approach is that the permutations generated from the crossover operation are guaranteed to be precedence feasible.

In case of binary strings, during the crossover stage, parent chromosomes are swapped as shown in Fig. 2. Child 1 is produced by taking initial part of parent 1 and tail part of parent 2. Similarly for child 2, initial part is taken from parent 2 and tail end from parent1. This allows greater freedom in generating children. In case of Hartmann's one point crossover, child 1 is produced by taking initial part from the parent 1 and then the parent 2 list is scanned from the beginning and those activities which are not part of the initial part and considered as shown in Fig. 3. This ensures precedence feasibility of child.

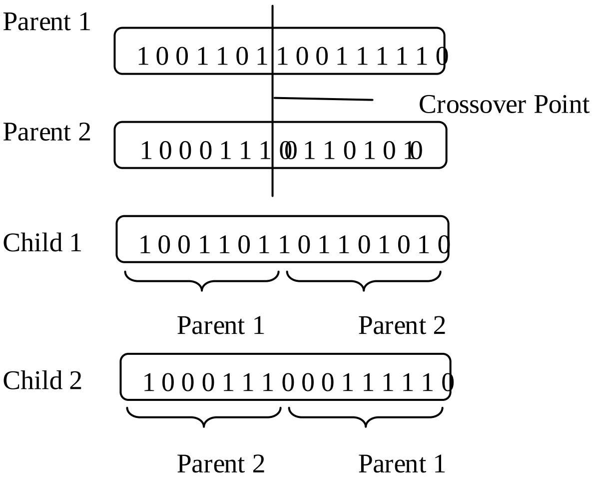

Fig 2: Bit level encoding and Genetic Operations [18]

Parent 1 1 2 4 5 3
Crossover Point
Parent 2 4 1 2 3 5

1 2 4 3 5
Child 1
Child 2 4 1 2 5 3

Fig 3: Permutation Encoding and Genetic Operations[18]

The existing Genetic Algorithms based methods proposed by Hartmann (1998) are very powerful for large test problems.

B] PSO for RCPS Problem:

PSO is an evolutionary computation technique proposed by Kennedy and Eberhart. PSO algorithm is based on social behaviors expressed by birds. To understand this technique, consider the following scenario: "Groups of birds are searching for food in special area where only one piece of food exists, of which birds are unaware. Birds, although, know their distance from the food at each moment. At this time, a good strategy to find the food is following the bird which is closer to the food. In fact, PSO algorithm is inspired from such a scenario to offer optimization solutions [6].

PSO algorithm is based on the fact that each particle determines its position at any moment based on the best position where it—and its neighbors—have so far been placed. Each individual or potential solution, called a particle, flies in the D-dimensional problem space with a velocity that is dynamically adjusted according to the flying experience of the individual and its colleagues. Each particle remembers the best position that it has found so far during the search process personal best (pbest), and knows the best position of the swarm global best (gbest). Therefore, each particle interacts with other and every particle in the swarm tries to gradually move toward the promising areas of the search space and in this way an optimum solution is found.

Steps involved in PSO algorithm
1. Initialize the swarm of particles to the solution space
2. Evaluate the fitness of each particle.
3. Update individual and global bests.
4. Update velocity and position of each particle.
5. Go to step 2, and repeat until termination condition.

Sr.No	Algorithm	Reference
1	GA 1	Hartmann, 1998
2	GA 2	Hartmann, 1998
3	SA	(Bouleimen and Lecocq, 1998)
4	GA 3	(Leon and Ramamoorthy, 1995)
5	Adaptive sampling 1	(Schirmer, 1998)

Fig.4 Optimization Algorithm for RCPS

V. CONCLUSION

The resource-constrained scheduling problem is one of the most challenging ones in the area of project management. This paper was reviews RCPS problem and different optimization algorithm so far used to find optimal solution in this area. Researches will be used to hybridization techniques of GA and PSO or PSO and SA for better improvement in result.

REFERENCES

[1] Farhad Habibi, Farnaz Barzinpour, "Resource-constrained project scheduling problem: review of past and recent developments", Journal of Project Management 3 (2018), 55-58
[2] Amer M. Fahmy," Optimization Algorithms in Project Scheduling", Optimization Algorithms-Methods and Applications chapter 8
[3] Shuai Li, Zhicong Zhang," Research on a resource-constrained project scheduling problem in hazardous environment and its stuffing strategies based on PSO algorithm", System science and control Engg. (2018), Vol 6 No.1 PP 304-308.
[4] Sofia Kaiafa, Athanasios P. Chassiakos," A genetic

algorithm for optimal resource-driven project scheduling",Science DirectProcedia Engineering 123 (2015) 260 – 267
[5] Sylverin Kemmo, Michel Gourgand," Solving Resource-Constrained Project scheduling problem with PSO",MISTA 2007
[6] Abdolvahab Raeisi Dana," Assessing the Application of PSO in project scheduling problem with limited resources", ISSN: 2277-5536 (Print); 2277-5641 (Online)
[7] J. Blazewicz, "Scheduling subject to resource constraints: classification and complexity", Discrete Applied Mathematics 5 (1983) 1 l-24
[8] Hartmann, S. (1998). "A competitive genetic algorithm for resource-constrained project scheduling". Naval Research Logistics 45, 733-750.
[9] Alcaraz, J., & Maroto, C. (2001). "A robust genetic algorithm for resource allocation in project scheduling". Annals of Operations Research 102, 83-109.
[10] Valls, V., Ballestin, F., & Quintanilla, M.S. (2008). "A hybrid genetic algorithm for the resource-constrained project scheduling problem". European Journal of Operational Research 185(2), 495-508.
[11] Chen, R.M. (2011). "Particle swarm optimization with justification and designed mechanisms for resource-constrained project scheduling problem". Expert Systems with Applications 38, 7102-7111.
[12] Zhang, H., Li, H., & Tam, C. M. (2005). "Particle swarm optimization-based schemes for resource-constrained project scheduling". Automation in construction 14 ,393-403
[13] Lo, S. T., Chen, R. M., Huang, Y. M., & Wu, C. L. (2008). " Multiprocessor system scheduling with precedence and resource constraints using an enhanced ant colony system". Expert Systems with Applications 34(3), 2071-2081.
[14] Thomas, P. R., & Salhi, S. (1998)."A tabu search approach for the resource constrained project scheduling problem". Journal of Heuristics, 4(2), 123-139.
[15] Kirkpatrick, S, Gelatt, C. D, & Vecchi, M. P. (1983). "Optimization by Simulated Annealing". Science. 220(4598), 671-680.
[16] Holland, H.J. (1975). "Adaptation in Natural and Artificial Systems". The University of Michigan Press, Ann Arbor.
[17] Goldberg, David (1989). "Genetic Algorithms in Search, Optimization and Machine Learning". Addison-Wesley Professional, Boston, MA.
[18] S Diana, L Ganapathy." An Improved Genetic Algorithm for Resource Constrained Project Scheduling Problem", International Journal of Computer Applications (0975 – 8887) Volume 78 – No.9, September 2013

