AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
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Resource Constrained Project Scheduling Using Genetic Algorithm

A Thesis Submitted in partial fulfillment of the requirements of the Degree of M.Sc. in Mechanical Engineering

By

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STATEMENT

This thesis is submitted in the partial fulfillment of Master degree in Mechanical Engineering to Ain Shams University.

The author carried out the work included in this thesis, and no part of this thesis has been submitted for a degree or qualification at any other university.

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Summary of the Master Thesis

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Resources constrained project scheduling problem is very common in industry and one of the most complicated problems to be tackled.

The problem is considered as an NP-Hard optimization problem; especially, when a set of large number of activities need to be finished as soon as possible, subject to two sets of constraints (precedence constraints, and resources constraints).

Researchers have developed numerous scheduling methods and techniques to overcome the complex nature of this problem.

Genetic Algorithms are very promising approaches to solve this problem, in terms of the computational feasibility, and the quality of the solutions. However, the most common models of the genetic algorithms are difficult to be implemented in scheduling problems. On the other hand, using specific and proper design of the genetic algorithms can make the scheduling problems tractable.

The objective of this work is:

- To introduce genetic algorithm search model, to solve the resources constrained project scheduling problem, considering the make span minimization as the objective function, subject to the activities precedence relations, and the limited resources, as the problem constraints.
- To study the effect of the genetic algorithm model operators' parameters and combinations (crossover and mutation) on the solution quality, and test a new developed (Ranged crossover) operator.

In order to achieve the work objectives, the model was constructed using the activity list permutation based chromosomes representation, different crossover

operators are incorporated in the model (Single Point Crossover, Two points Crossover, Partially Mapped Crossover, and a new developed Ranged crossover operator), additionally two types of mutation operators are parts of the model operators), with a predefined number of generations, that considered as the model run exit criterion.

In order to run this model, an interface software program is developed, to utilize Genetic algorithm library developed by Malden Janković, to test 30 different PSPLib library instances, grouped in three sets, the 30 activities set (J30), the 60 activities set (J60), and the 120 activities set (J120).

The developed program enables the user to easily tailor the genetic algorithm parameters, which opens the room of opportunities for further research on the impact of different parameters.

Three sets of experiments are carried out on each instances set, with a total of 80 experiments are taken place, comparing four different crossover operators, with the two different mutation operators.

The proposed model is applied on the (J30, J60, J120) PSPlib benchmark project instances sets. Each project instance set includes 10 different project scenarios. The results compared by the benchmark solutions.

The results showed promising performance of the proposed model. The new developed Ranged crossover operator, accompanied with the swap mutation operator, achieved the benchmark best solution, and improved the GA solution by 7% in Set-1 test runs, 1% in Set-2, and the proposed GA model with the partially mapped crossover, achieved the GA best solution in Set-3 test runs.

Using the proposed model, the average computation time is Improved by 67%, 31%, and 96% in Experiment-set1, Experiment-set2, Experiment-set3 test runs respectively, compared by the benchmark best solutions average computation time, using Intel (R) Core™i5 CPU 2.67GHz machine processor.

Finally, the model proves applicability, and opens wider opportunities to build on for further research work.

Key Words: Genetic Algorithm, Resources Constrained Project Scheduling, Crossover, Mutation.

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List of Abbreviations:

CPM	Critical Path Method
DC-RCPSP	Discounted Cash-flow Resource Constrained Project Scheduling Problem
GA	Genetic Algorithm
GPR	General Precedence Relation
LFT	Latest Finish Time
LST	Latest Start Time
MMRCPSP	Multi-Mode Resource Constrained Project Scheduling Problem
MSLK	Minimum Slack Time
MTS	Most Total Successor
NPV-RCPSP	Net Present Value Resource Constrained Project Scheduling Problem
OX	Order Crossover
PMX	Partially Mapped Crossover
PSGS	Parallel Schedule Generation Scheme
PSPlib	Project Scheduling Problems Library
RCPSP	Resource Constrained Project Scheduling Problem
RL-RCPSP	Resource Leveling Resource Constrained Project Scheduling Problem
RX	Ranged Crossover
SFT	Shift Mutation
SGS	Schedule Generation Scheme
SPX	Single Point Crossover
SSGS	Serial Schedule Generation Scheme
SWM	Swap Mutation
TPX	Two Point Crossover

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Introduction

The research is using the genetic algorithm as one of the powerful optimization tools. The usage of this tool has tremendously increased in the last decade, as observed by the increase in the number of published papers, conferences, and workshops.

Based on the biological evolutionary nature of the Genetic Algorithm (GA), in contrast to the local search techniques, GA is working on a set of populations of solutions, instead of only one individual, which guarantees better search in the solution space, with an effective computation time.

Researchers utilized the genetic algorithm as a searching technique in solving the combinatorial optimization problems.

The resources constrained project scheduling problem (RCPSP) is considered as one of the most complex optimization problems, and as one of the great challenges to different solution heuristics.

By the increase in the number of the project activities, and the number of constraints, the exact solutions, and the exhaustive search enumeration techniques, take a very high computational time to solve the problem, and sometimes fail to find the optimum solution. That is why researchers paid a lot of attention trying to solve the RCPSP using the GA.

The objective of this work is:

To investigate the capabilities of the GA in solving the Resources constrained project scheduling problem by:

- Testing different combinations of the GA operators to solve global project instances sets, using a Genetic library through a developed software interface testing environment.
- Developing a new crossover operator, and testing its capability in improving the solution quality.

The thesis is divided into the following chapters and appendices:

Chapter 1: A literature review is presented, concerning the application of the GA in solving the RCPSP. Objectives of the research are then set.

Chapter 2: Problem definition, modeling and assumptions are defined; outlines of the GA model and the developed crossover operator are discussed.

Chapter 3: The experiments' sets that are carried out to meet the research objectives are discussed.

Chapter 4: Results obtained for solving the problems (presented in appendix A) are introduced, discussed and compared.

Chapter 5: The conclusions are summarized, and the recommendations for future work are suggested.

Appendix A: Demonstration of the experimental work data.

Appendix B: Demonstration of the software program main structure.