Application of Memory-Based Approach to Multi-Objective Optimisation on Dynamic Resource-Constrained Project Scheduling with Time-varying Number of Tasks

by

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To the loving memory of my mother,

Consorcia Blanco Abello

and of my father,

Florencio Raz Abello

whose last words to me were:

"Finish your Ph.D."

...Done it, Dad.

Contents

List of Reserved Symbols

N	Total number of tasks
$\mathcal{P}^2$	Class of bi-objective dynamic RCPS problems, each with increases and without decrease in total number of tasks and has four types of resources
$\mathcal{P}^3$	Class of tri-objective dynamic RCPS problems, each with increases and without decrease in total number of tasks and has four types of resources
$\mathcal{C}^2$	Class of bi-objective dynamic RCPS problems, each with fixed total number of tasks
$\mathcal{L}^2$	Set of problems from $\mathcal{P}^2$ that have labels of one to 30 listed in Table 4.5
$\mathcal{L}^3$	Set of tri-objective counterparts of $\mathcal{L}^2$
$\mathcal{M}$	Class of multi-objective dynamic RCPS problems, each with increasing total number of tasks
$\mathcal{O}^2$	Subset of $\mathcal{Q}^2$
$\mathcal{Q}^2$	Class of bi-objective dynamic RCPS problems, each with increases and without decrease in the total number of tasks and has two types of resources
$\mathcal{X}^2$	a subset of $\mathcal{O}^2$ that is comprised of DOE-designed problems
BBD	Box-Behnken Design
CBAR	Centroid-Based Adaptation with Random Immigrants

CCD	Central Composite Design
EA	Evolutionary Algorithm
EDA	Estimation of Distribution Algorithm
McBAR	Mapping of Task IDs for CBAR
MCS	Monte Carlo Simulation
MOE	Military Operation Environment
MOO	Multi-Objective Optimisation
NSGA-II	Non-Dominated Sorting Genetic Algorithm-II
PNT	Precedence Network of Tasks
RCPS	Resource-Constrained Project Scheduling
RSM	Response Surface Methodology
SOSA	Sequential Order of State Alteration
TNIS	Task Number Increase Sequence
TSC	Type of sequence of changes

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Abstract

Many, if not all, manufacturing processes in industry require scheduling activities; such activities are very important as often they determine the success or failure of some companies. For example, in wine production, grapes are planted, mature fruits are harvested, transported and crushed then the juice obtained is placed in tanks, which are managed during fermentation, and finally the wine is bottle. A schedule can be a solution to a problem which has several, possibly conflicting objectives, e.g. the mininisation of production costs and delays while meeting customer-imposed wine delivery times; the problem also has constraints, e.g. a bottling line cannot be used without being cleaned to process white wine when it last processed red wine. As can be expected, the problem has variables such as the number of wine bottles ordered.

The environment (e.g. wine factory) in which the schedule is implemented may change (e.g. one bottling line breaks down) whereby this schedule becomes infeasible. Consequently, there could be a need to solve a new scheduling problem to obtain a new schedule best suited to the new state of the environment. The number of variables in this new problem may be the same as that of the previous problem. A large proportion of research effort has been directed towards scheduling problems with a constant number of variables despite changes in the environments where the problems are set. However, there are important scheduling problems where the number of variables could vary. For example, in some models of job-shop scheduling problems there are occurrences of additional rush jobs and job cancellations.

This thesis deals with one particular class of scheduling problems, each being multi-objective, resource constrained, and having numbers and values of variables which vary over time. Various traditional operation research methods as well as a few Artificial Intelligence-based techniques, such as Multi-Agent Systems and Evolutionary Algorithms (EA), have been applied to solve this type of problem. In this thesis, a memory-based EA technique was applied to solve problems from the class. Being memory-based, this technique utilises the solutions to problems set in previous states of an environment in

order to solve a problem set in the current state of this environment.

The memory-based EA technique, referred to as *Centroid-Based Adaptation with Random Immigrants* (CBAR), is applicable only to solve multi-objective, resource-constrained problems with a constant number of variables. In this thesis, CBAR is extended to become applicable to solve all problems from the above-mentioned class. The result of this extension is a technique referred to as *Mapping of Task IDs for CBAR* (McBAR).

This thesis investigates the performance, the performance stability over environmental dynamics, and the efficiency of McBAR for solving various problems from the above class, legitimises the sub-algorithms that constitute McBAR and extends McBAR to become proactive (anticipative of future environmental changes).

Compared to the other techniques investigated in this thesis, results showed McBAR to have the best and most stable performance, and to be most efficient for determining solutions to problems from the above class. All of the sub-algorithms of McBAR are shown to be legitimate, while McBAR having been made proactive is shown to be beneficial in some applications.

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[1]The final edition of this thesis was made exactly on the feast day of Saint Anthony.

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