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ORIGINAL ARTICLE

Using Fuzzy Clustering Chaotic-based Differential Evolution to solve multiple resources leveling in the multiple projects scheduling problem

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Abstract Project scheduling is an important part of construction project planning. Resource leveling is the process used within project scheduling to reduce fluctuations in resource usage over the period of project implementation. These fluctuations frequently create the untenable requirement of regularly hiring and firing temporary staff resources to meet short-term project needs. Construction project decision makers currently rely on experience-based methods to manage fluctuations. However, these methods lack consistency and may result in unnecessary wastage of resources or costly schedule overruns. This research introduces a novel optimization model called the Fuzzy Clustering Chaotic-based Differential Evolution for solving multiple resources leveling in the multiple projects scheduling problem (FCDE-MRLMP). The novel Fuzzy Clustering Chaotic-based Differential Evolution (FCDE) algorithm integrates fuzzy c-means clustering and chaotic techniques into the original Differential Evolution (DE) algorithm to handle complex optimization problems. The chaotic technique prevents the optimization algorithm from converging prematurely. The fuzzy c-means clustering technique acts as several multi-parent crossover operators in order to utilize population information efficiently and enhance convergence efficiency. Experiments run indicate that the proposed model obtains optimal results more reliably and efficiently than the benchmark algorithms considered. The proposed optimization model is a promising alternative approach to assist project managers to handle resource-leveling project scheduling problems effectively.

1. Introduction

Managing corporate resources efficiently is critical to the long-term success and sustainability development of a construction company [1]. The efficient management helps on keeping

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Nomenclature

Abbreviations and symbols

FCDE	Fuzzy Clustering Chaotic-based Differential Evolution
MRLMP	multiple resources leveling in the multiple projects
DE	Differential Evolution
PSO	Particle Swarm Optimization
GA	Genetic Algorithm
CLS	chaotic local search
AHP	analytical hierarchy process
FCM	fuzzy c-means
CDE	Chaos Differential Evolution
NFE	number of function evaluations
RI	resource intensity
w_m	weight score
λ	amplifying coefficient
LB	lower bound
UB	upper bound
F	mutation scale factor
CR	crossover probability
NP	population size
G	current generation
$G_{\max}$	maximum of generation
D	dimension of solution vector
m	clustering period
CF	percentage of population to chaos
μ	control parameter in chaos algorithm

operational expenses within planned budget and schedules on time. Time overruns often cause financial loss to the owner due to delays in facility availability [2] and may spark contract disputes that raise operational costs, degrade the company's reputation, and occasionally lead to project failure [3,4].

Construction resources primarily consist of manpower, equipment, materials, funds, and expertise. Construction schedules generated by using network scheduling techniques that often cause resource fluctuations are impractical, inefficient, and costly to implement [5,6]. Therefore, construction managers must adjust construction schedules manually to eliminate these fluctuations.

Resource fluctuations are a troublesome issue for contractors [7] because hiring and firing workers to harmonize with fluctuating resource profiles are impractical. However, resources must be managed efficiently in order to maximize resource expenditures and meet contracted schedules. Contractors are thus inevitably burdened by a certain percentage of idle resources during periods of low demand, which detracts from project profits.

The process of smoothing out resources, known as resource leveling, has been studied extensively [8–11]. Resource leveling attempts to minimize both the demand peak and the fluctuations in the pattern of resource usage [12,13] by optimizing noncritical activities within their available floats while keeping the project duration unchanged. The application of Evolutionary Algorithms (EAs) to resource leveling has attracted increasing attention in recent years [14–16]. Based on the principles of natural evolution, EAs are stochastic optimization techniques that have successfully resolved optimization problems in diverse fields [17]. However, EAs suffer from certain weaknesses. Geng et al. [14] identified premature convergence and poor exploitation as the main obstacles preventing EAs from coping effectively with complex optimization problems.

Research on resource leveling has focused mainly on three aspects: (1) single-resource leveling in single-project scheduling, (2) multiple-resource leveling in single-project scheduling, and (3) single-resource leveling in multiple-project scheduling. However, multiple-resource leveling in multiple-project scheduling is the most typical scenario in the construction and manufacturing industries, a situation that is relatively more complex and difficult due to the lack of a standard handling procedure [16]. Thus, developing a methodology for multiple-resource leveling in multiple-project problems and a more efficient algorithm to attain better resource-leveling-problem solutions are essential to improve the management of construction project resources.

The Differential Evolution (DE) [18] algorithm is an evolutionary computation technique. DE has drawn increasing interest from researchers, who have explored the capabilities of this algorithm in a wide range of problems. DE is a population-based stochastic search engine that is efficient and effective for global optimization in the continuous domain. DE uses mutation, crossover, and selection operators at each generation to move a population toward the global optimum. The superior performance of DE over competing algorithms has been verified in multiple published research works [19–21].

Despite these advantages, the original DE and its numerous variants have some drawbacks. DE does not guarantee convergence to the global optimum and is easily trapped in local optima, resulting in low optimization precision or even optimization failure [22]. Further, populations may not be distributed over the search space, potentially trapping individuals in a local solution. DE may also require more generations than competing algorithms to converge on the optimal or near-optimal solution [23]. DE is particularly weak in situations in which the global optimum must be located using a limited number of fitness function evaluations. Finally, although DE is good at exploring the search space and locating the region of global minimum, it is slow to exploit the solution [24].

The inherent characteristics of chaotic systems provide an efficient approach maintaining population diversity in search algorithms. Chaos is the irregular motion of a deterministic nonlinear system under deterministic conditions. Because chaotic systems are sensitive to small differences in initial conditions, they may widely generate variant outcomes. This extreme sensitivity to initial conditions reflects the so-called butterfly effect or Liapunove's sense [25]. Some studies have hybridized DE with the chaotic algorithm. Jia et al. [22] combined chaotic local search (CLS) with a "shrinking" strategy. The CLS helps improve the optimizing performance of the canonical DE by exploring a huge search space in the early run phase to avoid premature convergence and exploiting a