Chapter 12
Lévy-Enhanced Swarm Intelligence for Optimizing a Multiobjective Biofuel Supply Chain

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ABSTRACT

Engineering systems are currently plagued by various complexities and uncertainties. Metaheuristics have emerged as an essential tool for effective engineering design and operations. Nevertheless, conventional metaheuristics still struggle to reach optimality in the face of highly complex engineering problems. Aiming to further boost the performance of conventional metaheuristics, strategies such as hybridization and various enhancements have been added into the existing solution methods. In this work, swarm intelligence techniques were employed to solve the real-world, large-scale biofuel supply chain problem. Additionally, the supply chain problem considered in this chapter is multiobjective (MO) in nature. Comparative analysis was then performed on the swarm techniques. To further enhance the search capability of the best solution method (GSA), the Lévy flight component from the Cuckoo Search (CS) algorithm was incorporated into the Gravitational Search Algorithm (GSA) technique; developing the novel Lévy-GSA technique. Measurement metrics were then utilized to analyze the results.

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INTRODUCTION

Optimization efforts in engineering are often plagued by various complexities and uncertainties. Hence the computational capability of metaheuristic algorithms is indispensable when tackling such problems (Ganesan et al., 2016a; Ganesan et al., 2018a; Yang, 2013). Among the complexities arising are: high levels of nonlinearity, many target objectives, non-convexity and multiple variables. The existence of all these complexities in a single problem could potentially overwhelm the solution method (conventional metaheuristics) - resulting in the failure of the method to reach the optimal solution. To further boost conventional metaheuristics, algorithms are hybridized as well as enhanced (Ganesan et al., 2015; Ganesan et al., 2018b; Hong et al., 2016; Dong et al., 2016). For dealing with optimization problems which have multiple objectives, various algorithms such as Non-Dominated Sorting Genetic Algorithm (NSGA-II) (Mousavi et al., 2016), Strength Pareto Evolutionary Algorithm (SPEA-2) (Zhao et al., 2016), weighted sum (Naidu et al., 2014) and the Normal-Boundary Intersection (NBI) (Ahmadi et al., 2015) have been developed. Scalarization approaches such as the weighted sum technique and NBI enable multiple objectives to be aggregated into a single-objective problem. Transforming the problem this way significantly reduces its complexity making it easier to solve.

Supply chain planning/optimization present various challenges to decision makers globally. This is due to its highly complicated nature as well as its large-scale structure. Over the years various state-of-the-art methods have been employed to model supply chains (Seuring, 2013; Brandenburg et al., 2014; Ahi and Searcy, 2013). Optimization techniques are then applied to such models to help with optimal decision making (Ogunbanwo et al., 2014; Mastrocinque et al., 2013).

Fuel supply chains have recently picked up interest by researchers in academia as well as decision makers in various industries (Ba et al., 2016; Yue et al., 2014; Ghaderi et al., 2016). Modeling and optimizing these large-scale fuel supply chains have deemed to be challenging. An example of such a model development could be seen in the work of Awudu and Zhang (2013). In that work, the authors proposed a stochastic planning model for a biofuel supply chain. The supply chain consisted of biomass suppliers, biofuel refinery plants and distribution centers. Targeted at optimizing profits, the Geometric Brownian Motion and Benders decomposition method with Monte Carlo simulation was applied. Besides benchmarking their stochastic model against a deterministic model, the authors performed sensitivity analysis on various parameters using their model. Another work towards modeling fuel supply chains was presented in Poudel et al. (2016). There a pre-disaster planning model was developed to strengthen the biofuel supply chain system. The pre-disaster model considered the linking and selection of facilities that reflected the post-disaster connectivity and biofuel-related costs. The model was developed using the generalized Bender's decomposition algorithm and validated using industrial data from Mississippi and Alabama, United States.

On the other hand, the optimization work in Lin et al., (2014) aimed to minimize the annual biomass-ethanol production costs. The supply chain problem solved in that work was a large-scale model consisting of biomass harvesting, stacking, in-field transportation, transportation, preprocessing, packing and storage, to ethanol production and distribution. Using the mixed integer programming technique, the authors managed to reduce the cost of production (biorefinery) by 62%. A similar work was carried out in Zhang et al. (2013), where the switchgrass-based bioethanol supply chain was modelled and optimized. The location of study was North Dakota, United States. Similar to Lin et al. (2014), the model was optimized using mixed integer linear programming - obtaining optimal usage of marginal land for switchgrass production to harvest bioethanol in a sustainable and economical manner. In Osmani and

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