Engineering Applications of Artificial Intelligence 37 (2015) 154–169

Contents lists available at ScienceDirect

Engineering Applications of Artificial Intelligence

journal homepage: www.elsevier.com/locate/engappai

Swarm intelligence applied in green logistics: A literature review

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ARTICLE INFO

Article history:
Received 12 May 2014
Received in revised form
4 September 2014
Accepted 13 September 2014
Available online 8 October 2014

Keywords:
Swarm intelligence
Green logistics
Reverse logistics
Closed-loop supply chain
Literature review
Optimization

ABSTRACT

Green logistics (GL) is gaining increasing attention among academic researchers and industrial practitioners, due to the escalating deterioration of the environment. Various green activities and operations aiming at improving the performance of GL have been applied synthetically, and most of the activities can be modeled as combinatorial optimization (CO) problems. Exact approaches tend to be incapable of solving the CO problems, especially with the increasing complexity. Thus, meta-heuristic approaches are widely adopted, which can generate a satisfactory solution within an acceptable time. Swarm intelligence (SI) is an innovative branch of meta-heuristics derived from imitating the behavioral pattern of natural insects. The distributed control mechanism and simple interactive rules can manage the swarm of insects effectively and efficiently. There are some pilot studies in applying SI into GL, which indicates that the integration of GL and SI could be a promising choice and of great potential. This research reviews the application of SI in GL through a comprehensive and extensive investigation and analysis of extant literature, which includes 115 publications in the last twenty years. The integration of GL and SI is analyzed from the perspective of both the problem context and the methodology. The categories of GL and SI are classified systematically. The CO problems of GL are further studied with SI algorithms, and innovative and universal guidance for algorithm customization in resolving CO problems emerges as well. Further potential research issues and opportunities of GL and SI are also identified in this research.

1. Introduction

Global warming, environment deterioration, and government regulations arouse the awareness of academic researchers and industrial practitioners for considering the "green" strategies in logistics industry (Murphy, 2000). Green Logistics (GL) concerns not only the provision of green products or services to customers, but also the overall logistics flow of items from cradle to grave, together with reverse logistics. Various green activities and operations have been implemented, such as production scheduling and network construction. In order to improve the performance of GL, individual logistics parties not only need to implement green activities and operations by themselves, but also the cooperation and collaboration among different logistics parties (Zhou et al., 2000). The performance of GL cannot be measured simply in an economic way, but in a sustainable way taking account of environmental and societal factors as well, which are also the objectives of GL (Björklund et al., 2012; Hervani et al., 2005). GL can be understood as the combination of traditional logistics and reverse logistics (RL). Traditional logistics comprises the flow from the raw materials to finished products, while RL is a rather new research field, which involves the concept of recycling used products in order to reduce waste and to increase an industry's performance and resulting profits. RL is of great importance, as it not only complements integrated logistics research, but also improves the performance of GL significantly in terms of all the economic, environmental and societal objectives (Lee and Lam, 2012). RL also consists of numerous activities and operations, such as returned products collection, examination, pre-processing, recycling, remanufacturing or disposal (Rogers and Tibben-Lembke, 2001).

Most of the activities and operations in GL can be formulated as combinatorial optimization (CO) models with multiple objectives, constraints and decision variables. Exact methods, such as Linear Programming (LP) and Branch-and-Bound (B&B), are becoming less popular for solving CO problems, as they are either unable to solve complicated CO problems with large numbers of variables or it takes long time to find the solution for CO problems (Laporte, 1992). By contrast, meta-heuristic approaches are becoming increasingly popular as these approaches are approximate approaches, which suggest that they could find satisfactory solutions within an acceptable time instead of finding the optimal solution. Intuitively speaking, meta-heuristic approaches can be classified into two categories: the

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http://dx.doi.org/10.1016/j.engappai.2014.09.007
0952-1976/

single-solution based approaches and the population based approaches (Blum and Roli, 2003). The single-solution based approaches, also named the trajectory methods (Consoli and Darby-Dowman, 2007), such as Tabu Search (TS), Simulated Annealing (SA) and various local search methods, in that only one candidate solution exists during the whole search process. However, the population based approach indicates that the search process starts with a population of candidate choices, and the whole population further evolves. The advantages and disadvantages of both the single-solution based approaches and the population based approaches can be found in the literature (Glover and Kochenberger, 2003; Jones et al., 2002). Two important examples of the population based approach are Evolutionary Algorithms (EAs) and Swarm intelligence (SI). The most typical example of EAs is the Genetic Algorithm (GA), which was proposed by Holland in 1975 and simulates the Darwin evolution concept (Holland, 1975).

SI approaches were originally inspired by the collective behavior of natural species, such as ant colony optimization (ACO) from ants, Particle Swarm Optimization (PSO) from birds and the Artificial Bee Colony (ABC) from bees (Bonabeau et al., 1999). SI is a relatively new branch of meta-heuristics comparing with EAs and other single-solution based approaches. SI approaches use approximate and non-deterministic strategies to effectively and efficiently explore and exploit the search space in order to find near-optimal solutions (Blum and Li, 2008; Blum and Merkle, 2008). SI has three fundamental and essential properties, namely decentralization, self-organization and collective behavior, which are necessary and sufficient to acquire SI behaviors. Decentralization means that no central control mechanism exists. The behaviors of individuals are determined by themselves. And the self-organization of individual relies upon four fundamental properties, i.e. positive feedback, negative feedback, fluctuations and multiple interactions (Jeanne, 1986). The interaction between two individuals or environment follows simple rules. The result from interaction would either impel or restrain the behavior of certain individual as positive feedback or negative feedback. The decision of certain individual might be affected by some random factors, which leads to fluctuations. Collective behavior refers that in a swarm, the individual behavior may act randomly, however the aggregation of individual behavior turns to be globally intelligent. In other words, SI indicates that a number of cognitive individuals accumulate their knowledge through the interaction with other individuals or the environment, determine their behaviors solely and finally achieve the target. The characteristics and details of each SI approach are presented in Section 4.

Ever since the introduction of SI, various SI algorithms have been proposed and applied to solve the CO problems in multifarious disciplines, among which the domain of GL could be a promising research area due to its inherent characteristics and features. However, given that there have been many researches of solving GL problems using SI algorithms. Most of them are individually separated, either solving an independent GL problem or adopting a single SI algorithm. In this regard, a comprehensive and extensive literature review of the integration of GL and SI from both the problem context and the methodology perspective is needed urgently. In this research, the state-of-the-art applications of the SI algorithms in the GL background are fully investigated and analyzed, and can help researchers to obtain an intuitive and profound understanding of current research situations. In addition, considering the implementation of various SI algorithms and their variants, this research also provides innovative and universal principles of algorithm selection, improvement and even customization through detailed algorithm analysis and comparison, which can offer practical guidance when solving CO problems using SI related algorithms.

After a brief introduction, the research methodology, i.e. the process of literature review, is described in Section 2. The classification schemes of GL and SI are presented in Sections 3 and 4 respectively. Section 5 discusses the integration of GL and SI and the guiding principles of choosing and optimizing algorithms for specific problems is presented Finally, Section 6 concludes the work and suggests research opportunities and directions for further work.

2. Research methodology

The objective of this research is to identify major works on interdisciplinary research in GL and SI, and thereafter, to classify and integrate them so as to discover gaps, critical issues and opportunities for further study and research. The literature review is a valid approach and necessary step in exploring new research directions and forms an integral part of the related research, which also helps to scrutinize the conceptual aspects and guides the research toward new theoretical development (Meredith, 1993; Seuring and Müller, 2008). The literature review is conducted for content analysis, where quantitative and qualitative aspects are reviewed to assess the context as well as the content (Brewerton and Millward, 2001). The process of this literature review follows the four-step process model proposed by Mayring (2004); material collection, descriptive analysis, category selection, and material evaluation, described in Fig. 1, and the review process is carried out accordingly.

With the inherent nature of research related to GL and SI, the targeted publications should mostly comprise operational-level CO models, e.g. transportation problems, network design problems, production scheduling problem, etc. solved by SI related approaches. With this consideration, the following databases were selected for a comprehensive and extensive review of this interdisciplinary research: IEEE/IEE Electronic Library via IEEE Xplore, ScienceDirect by Elsevier, Scopus, and SpingerLink. In addition to those databases, Google Scholar was also used to complement the related publications. The

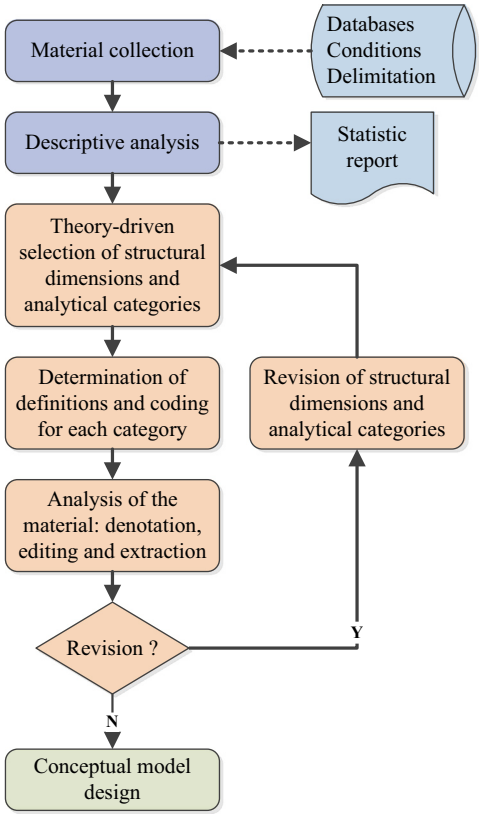

Fig. 1. The flow chart of literature review.