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A review of applications of genetic algorithms in operations management

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ABSTRACT

Many decisions in operations management (OM) belong to the class of Non-deterministic Polynomial hard problems and thus heuristic search methods have been applied to improve OM decisions. While genetic algorithms (GAs) are promising tools for searching fast and good solutions in diverse OM areas, future research will benefit from a review of the OM problems solved by GAs. The purpose of this paper is to review the literature on OM with GA-based solutions and to suggest possible gaps from the point of view of researchers and practitioners. A total of 119 peer reviewed journal papers published from 2007 to 2017 are reviewed and analysed methodologically. The applications of GAs in OM are categorized into process and product design, operations planning and control, and operations improvement. Observations from the existing literature are presented and future research directions are suggested. Although GAs have been one of the most popular heuristic approaches for optimization, there are OM problems that are yet to be investigated. The findings of this review pave the path for future research to apply GAs to solve OM problems.

1. Introduction

Operations management (OM) is the activity of managing the resources that create and deliver services and products (Slack et al., 2013). All organizations need operations to produce some mix of services and products. In any organization, three core functions are the marketing function, product/service development function and operations function. The marketing function is responsible for communicating the services and products to its markets to generate customer requests; the product/service development function is responsible for coming up with new or modified services and products to generate future customers' requests; the operations function is responsible for creating and delivering services and products based on customer requests. In practice, however, there is not a clear division among these three functions while there exist other support functions enabling the core functions. From a broad perspective, OM has to interact with all other functions of an organization and thus comprises all activities necessary for the day-to-day fulfilment of customer requests. Many decisions in OM can be characterized as complex optimization problems that require a heuristic search method. Therefore, OM is an active research area benefited from the use of artificial intelligence (AI) techniques such as genetic algorithms (GAs) in the search for fast and good solutions to many practical problems. While GAs seem to be promising tools for solving OM related problems, a systematic review of applications of GAs in OM can help researchers to identify potential research areas and future directions.

The aim of the paper is to explore OM using GAs as useful tools, either as a standalone technique or integrated with other suitable techniques. However, for ease of exposition, some developments of GAs in the review are not included. First, though GAs are included in the evolutionary computation (EC) field, other EC methods or Darwinian approaches are not included in this paper. This is because these approaches deserve a separate review. For a detailed literature review of bio-inspired computing algorithms, readers are referred to a recent review by Kar (2016). Second, in line with the focus of this paper, the theoretical developments of the algorithms are not explored. There are many variants of GAs such as variable-length GAs and fuzzy GAs. Details of the modification of the algorithms are not discussed here. Instead, this paper focuses on the applications.

Given the growing number of GA applications, a number of papers surveying its applications have been published regularly. Coello (2000) provided a review of GA-based multi-objective optimization techniques. The discussion was at the technical side, and thus the applications of OM were not covered. Aguilar-Rivera et al. (2015) reviewed the GA applications in finance. In addition to GAs, they also reviewed other methods based on Darwinian evolution such as genetic programming, learning classifier systems, multi-objective evolutionary algorithms, co-evolutionary optimization schemes and competent evolutionary algorithms. In view of the fact that there are various focused areas in OM, some researchers reviewed applications of data mining and AI in particular areas, such as job-shop scheduling (Cheng et al., 1996),

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Table 1
Classification of OM areas.

Authors	Classification of OM areas
Mertens and Kanet (1986)	Production planning and control, materials control, purchasing, inventory management, forecasting, manufacturing engineering, industrial engineering, maintenance, quality control
Rao and Lingaraj (1988)	Aggregate planning, forecasting, location decisions, scheduling, capacity planning, layout, process and product design, quality control, job design, inventory control, maintenance and reliability
Partovi et al. (1990)	Forecasting, supplier selection, facility location, choice of technology, product design, plant layout, maintenance frequency selection, choice of logistic carrier
Schroeder (1993)	Quality management and control, process design, capacity planning and scheduling, inventory management, work-force management
Jayaraman and Srivastava (1996)	Process choice, process design, product design, quality planning, facility location, facility layout, project management, long-term capacity planning, job design, aggregate planning, long-term forecasting, short-term capacity planning, distribution, scheduling, quality control, inventory control, maintenance, short-term forecasting, purchasing
Proudlove et al. (1998)	Operations strategy, product design, quality management and control, process design, capacity planning and scheduling, inventory management, work-force management
Aytug et al. (2003)	Production control, facility layout design, line balancing, production planning, supply chain management and design, other
Chaudhry and Luo (2005)	Environment, process choice, process design, product design, quality planning, facility location, facility layout, project management, long-term capacity planning, job design, aggregate planning, long-term forecasting, short-term capacity planning, distribution, scheduling, quality control, inventory control, maintenance, short-term forecasting, purchasing
Kobbacy and Vadera (2011)	Design, scheduling, process planning and control, quality, maintenance and fault diagnosis
Wong and Lai (2011)	Environment, process choice, process design, product design, quality planning, facility location, facility layout, project management, long-term capacity planning, aggregate planning, short-term capacity planning, distribution, scheduling, quality control, inventory control, maintenance, short-term forecasting, purchasing
Subramanian and Ramanathan (2012)	Operations strategy, process and product design, planning and scheduling resources, project management, managing the supply chain

supplier evaluation and selection (Ho et al., 2010), and quality improvement (Köksal et al., 2011). Ho et al. (2010) concluded that GA applications in supplier evaluation and selection were limited while Köksal et al. (2011) identified that GAs were frequently used for parameter optimization for quality improvement. There are a number of reviews in OM areas and different researchers classified them in different ways. Rao and Lingaraj (1988) classified OM applications into strategically and tactically oriented applications. They identified eleven areas: aggregate planning, forecasting, location decisions, scheduling, capacity planning, layout, process and product design, quality control, job design, inventory control, and maintenance and reliability. Aytug et al. (2003) classified OM areas into six categories: production control (e.g. loading and scheduling), facility layout design, line balancing, production planning, supply chain management and design, and other. Jayaraman and Srivastava (1996) identified nineteen areas under two board categories of strategic and operational decisions. Chaudhry and Luo (2005) adopted Jayaraman and Srivastava's (1996) classification scheme but added environment as an additional area to be considered under strategic decisions. Based on Chaudhry and Luo (2005) and Wong and Lai (2011) classified OM into eighteen areas for reviewing the applications of fuzzy set theory in production and OM. Kobbacy and Vadera (2011) reviewed AI in OM categorized into four areas: design, scheduling, process planning and control, and quality, maintenance and fault diagnosis. Subramanian and Ramanathan (2012) categorized OM into five broad themes: operations strategy, process and product design, planning and scheduling resources, project management, and managing the supply chain. The classification of OM areas by researchers is summarized in Table 1. To the best of our knowledge, there has not been a study that has reviewed GA applications in specific areas of OM, with the exception of a review by Chaudhry and Luo (2005), who presented a review of GA-related research published from 1990 to 2001. They did not discuss GA applications in specific OM areas individually in detail, but provided a journal-wise appearance of GA-related papers. This is considered a significant gap in the literature and this paper aims to provide an up-to-date review of GA applications in specific OM areas to fill the gap.

The rest of the paper is organized as follows. Section 2 describes the framework of the classification of GA applications in this paper. Section 3 presents a detailed review of GA applications in OM. Section 4 discusses the observations from the review and provides suggestions for future work. Section 5 concludes the paper.

2. A framework for classification

Based on Table 1, the applications of GAs in OM in this paper are categorized into three broad themes, namely (i) process and product design, (ii) operations planning and control, and (iii) operations improvement.
(i) ***Process and product design*** is a theme comprising design activities for satisfying customers' requirements through shaping or configuring products, services and processes. Activities in this theme determine the resources required for the creation of services and products. At the most strategic level, process and product design means shaping the networks of operations that supply products and services. At a more operational level, it means the arrangement of the processes and resources that constitute operations processes.
(ii) ***Operations planning and control*** is a theme dealing with the delivery of products and services. The key to an operation's ability to deliver is the way it plans its activities and controls them so that customer demand is satisfied. This theme covers activities related to planning and controlling resources which are capable of satisfying