Applications of Swarm Intelligence in Remanufacturing

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1. INTRODUCTION

Remanufacturing represents a new paradigm for thinking about how manufacturing and the environment relate. It is a growing field of research concentrating on reducing the environmental impact of used products on the capacity of the earth to sustain life. In a remanufacturing system, due to operation processes and supply is largely exogenous, the timing, quantity, and quality of supply are much more uncertain than in traditional production and distribution systems (Guide, Jayaraman, & Srivastava, 1999).

Swarm intelligence (SI) is one of the preferred choices to solve those problems. As more SI applications are introduced and used, a growing body of papers has been established that can guide the future design and development of remanufacturing solutions. This research aims at reviewing the common SI techniques applied to remanufacturing management, exploring the current research trends and identifying opportunities for further research. It is believed that the marriage of these two areas, SI in remanufacturing, represents an opportunity to increase the efficiency of the whole remanufacturing process, and result in a potentially far reaching economic, environmental, and societal influence.

The main issues to address include: what are the main problems within used products collection that have been investigated using SI techniques? What are the main findings and achievements up to date? What are the major obstacles that have ever been encountered and how might they be overcome?

The remainder of this article is organized as follows. Subsequent to the introduction in Section 1, the background of remanufacturing and SI is briefed in Section 2. Then, the existing studies of applying SI techniques to used products collection in remanufacturing management are examined in Section 3 which is followed by solutions and recommendations given in Section 4. Next, Section 5 highlights the future research directions. Finally, the conclusion drawn in Section 6 closes this article.

2. BACKGROUND

2.1. Remanufacturing

The remanufacturing is an end-of-life (EoL) strategy that reduces the use of raw materials and saves energy while preserving the value added during the design and manufacturing processes (Zwolinski, Lopez-Ontiveros, & Brissaud, 2006). A well-structured remanufacturing system should guarantee high efficiency, high functionality and a high customer orientation concerning the disposal of used household appliances. It should entail environmentally friendly solutions concerning energy consumption, emission of pollutants and noise as well as secure transportation.

The remanufacturable products can be sold at the secondary markets at a lower price, compared to the price of new products, e.g., tires (Ferrer, 1997), photocopiers (Ayres, Ferrer, & Leynseele, 1997), cell phones (Nikolaidis, 2009) or they can be used to satisfy demand of the same markets, e.g., single use cameras (Toktay, Wein, & Zenios, 2000), pallets and containers (Golany, Yang, & Yu, 2001; Kroon & Vrijens, 1995), car engines (Smith & Keoleian, 2004) and computer parts (Fleischmann, Nunen, & Gräve, 2003).

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2.2. Swarm Intelligence

Swarm intelligence (SI) is inspired by the collective behavior of social systems (such as fish schools, bird flocks and ant colonies). Formally, a swarm can be defined as a group of (generally mobile) agents that communicate with each other (either directly or indirectly), by acting on their local environment. The examples of such interactive behavior are bee dancing during the food procurement and ants' pheromone secretion. Those approaches are a growing discipline for problem solving of almost all engineering domain. In this review, three of the famous SI algorithms, namely ant colony optimization (ACO) (Dorigo, Maniezzo, & Colorni, 1996; Dorigo & Stützle, 2004), bees-inspired algorithms (D. Karaboga & Basturk, 2008), and particle swarm optimization (PSO) (Kennedy & Eberhart, 1995) will be intensive carried out.

1. Ant Colony Optimization

Ant colony optimization (ACO) algorithms are a relatively recent development among available methods for the solution of combinatorial optimization problems. According to the literature, the algorithms have taken inspirations from the foraging behavior of some real ant species. These ants deposit a substance called pheromone on the ground in order to mark some favorable path that could be followed by other members of the colony. ACO algorithms exploit a similar mechanism and show a good performance in solving problems that are combinatorial in nature. So far, there are a series of successful ACO variants existing in the literature such as ant system (AS) (Dorigo et al., 1996), Ant-Q (Gambardella & Dorigo, 1995), MAX-MIN ant system (MMAS) (Stützle & Hoos, 2000), and ant colony system (ACS) (Dorigo & Gambardella, 1997). These algorithms have been successfully applied to varied applications like assembly sequence planning (Wang, Liu, & Zhong, 2005); quadratic assignment problem (QAP) (Maniezzo, 1999; Xing, Gao, Nelwamondo, Battle, & Marwala, 2010b); scheduling problem (Blum, 2005); traveling salesman problem (TSP) (Gambardella & Dorigo, 1995; Xing, Gao, Nelwamondo, Battle, & Marwala, 2010a); and vehicle routing problem (VRP) (Bullnheimer, Hartl, & Strauß, 1997).

2. Particle Swarm Optimization

Particle swarm optimization (PSO) is a type of evolutionary computation proposed by Kennedy and Eberhart (1995) and this procedure was inspired by algorithms that model the "flocking behavior" seen in birds. The purpose was to demonstrate the idea of individuals gaining evolutionary advantage by sharing information. The PSO approach has the advantages in that it is computationally efficient, simple to implementation, has few adjustable parameters when compared to other competing evolutionary programming methods such as genetic algorithms (GA) and can adapt to the local and global exploratory ability (Kennedy & Eberhart, 1995). PSO has been very successful in optimizing many complex problems. A comprehensive review of the various multi-objective PSO was provided in (Reyes-Sierra & Coello, 2006) including a classification of the approaches, and the promising areas of future research.

3. Bees-Inspired Algorithms

The honey bees have photographic memories, space-age sensory and navigation systems and they perform tasks such as brood tending, foraging, retrieving and distributing honey. In recent years, based on those characteristics, a number of bees-inspired algorithms have been presented. Mainly, those algorithms are divided in two categories according to their foraging behavior such as artificial bee colony (ABC) algorithm, the virtual bee algorithm (VBA), the bee colony optimization (BCO) algorithm, the BeeHive algorithm, the bee swarm optimization (BSO) algorithm, and mating behavior such as honey bees mating optimization (HBMO). For more information please refer to (Dervis Karaboga & Akay, 2009; Marinakis, Marinaki, & Dounias, 2010; Xing & Gao, in press).

3. SI-BASED APPROACHES IN USED PRODUCT RETRIEVAL

Collection refers to all activities rendering used products available and physically moving them to some point where further treatment is conducted. In general,

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