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ScienceDirect
European Journal of Operational Research 179 (2007) 692–708
EUROPEAN JOURNAL OF OPERATIONAL RESEARCH
www.elsevier.com/locate/ejor

A balancing method and genetic algorithm for disassembly line balancing

Seamus M. McGovern, Surendra M. Gupta *

Laboratory for Responsible Manufacturing, Department of Mechanical and Industrial Engineering, Northeastern University, 334 SN, 360 Huntington Avenue, Boston, MA 02115, USA

Received 8 April 2004; accepted 9 March 2005
Available online 7 December 2005

Abstract

Disassembly activities take place in various recovery operations including remanufacturing, recycling and disposal. The disassembly line is the best choice for automated disassembly of returned products. It is therefore important that the disassembly line be designed and balanced so that it works as efficiently as possible. The disassembly line balancing problem seeks a sequence which: is feasible, minimizes workstations, and ensures similar idle times, as well as other end-of-life specific concerns. However finding the optimal balance is computationally intensive with exhaustive search quickly becoming prohibitively large even for relatively small products. In this paper the problem is mathematically defined and proven NP-complete. Additionally, a new formula for quantifying the level of balancing is proposed. A first-ever set of a priori instances to be used in the evaluation of any disassembly line balancing solution technique is then developed. Finally, a genetic algorithm is presented for obtaining optimal or near-optimal solutions for disassembly line balancing problems and examples are presented to illustrate implementation of the methodology.

Keywords: Genetic algorithm; Disassembly; Disassembly line balancing; Combinatorial optimization; Product recovery

1. Introduction

In recent years, the implementation of extended manufacturer responsibility together with new, more rigid environmental legislation and increased public awareness has caused a growing number of manufacturers to begin recycling and remanufacturing their post-consumed products after they are discarded by consumers. In addition, the economic attractiveness of reusing products, subassemblies or parts instead of disposing of them has further fueled this effort. Recycling is defined as a process performed to retrieve the material content of used and non-functioning products. Remanufacturing on the other hand is an industrial process in which worn-out products are restored to like-new

* Corresponding author. Tel.: +1 617 373 4846; fax: +1 617 373 2921.
E-mail address: gupta@neu.edu (S.M. Gupta).

0377-2217/$ - see front matter
doi:10.1016/j.ejor.2005.03.055

conditions. Thus, remanufacturing provides the quality standards of new products with used parts.

Product recovery aims to minimize the amount of waste sent to landfills by recovering materials and parts from old or outdated products by means of recycling and remanufacturing (including reuse of parts and products). There are many attributes of a product that enhance product recovery; examples include: ease of disassembly, modularity, type and compatibility of materials used, material identification markings and efficient cross-industrial reuse of common parts/materials. The first crucial step of product recovery is disassembly.

Disassembly is a methodical extraction of valuable parts/subassemblies and materials from discarded products through a series of operations. After disassembly, reusable parts/subassemblies are cleaned, refurbished, tested and directed to the part/subassembly inventory for remanufacturing operations. The recyclable materials can be sold to raw-material suppliers while the residuals are sent to landfills.

Disassembly has recently gained a great deal of attention in the literature due to its role in product recovery. A disassembly system faces many unique challenges; for example, it has significant inventory problems because of the disparity between the demands for certain parts or subassemblies and their yield from disassembly. The flow process is also different. As opposed to the normal "convergent" flow in regular assembly environment, in disassembly the flow process is "divergent" (a single product is broken down into many subassemblies and parts). There is also a high degree of uncertainty in the structure and the quality of the returned products. The condition of the products received is usually unknown and the reliability of the components is suspect. In addition, some parts of the product may cause pollution or may be hazardous. These parts tend to have a higher chance of being damaged and hence may require special handling which can also influence the utilization of the disassembly workstations. For example, an automobile slated for disassembly contains a variety of parts that are dangerous to remove and/or present a hazard to the environment such as the battery, airbags, fuel and oil. Various demand sources may also lead to complications in disassembly line balancing. The reusability of parts creates a demand for these parts however, the demands and availability of the reusable parts is significantly less predicable than what is found in the assembly process. Most products contain parts that are installed (and must be removed) in different attitudes, from different areas of the main structure, or in different directions. Since any required directional changes increases the setup time for the disassembly process, it is desirable to minimize the number of directional changes in the final disassembly sequence. Disassembly line balancing is critical in minimizing the use of valuable resources (such as time and money) invested in disassembly and maximizing the level of automation of the disassembly process and the quality of the parts or materials recovered.

In this paper the disassembly line balancing problem (DLBP) is solved using exhaustive search and a combinatorial optimization methodology. Exhaustive search consistently provides the optimal solution, though its exponential time complexity quickly reduces its practicality. Combinatorial optimization techniques however, are instrumental in obtaining optimal or near-optimal solutions to problems with intractably large solution spaces. An exhaustive search algorithm is presented for obtaining the optimal solution to small instances of the DLBP. A genetic algorithm (GA) is then presented for obtaining solutions for the DLBP. The genetic algorithm considered here involves a randomly generated initial population with crossover, mutation and fitness competition performed over many generations. An example from the literature is considered to illustrate the implementation of the methodology. The conclusions drawn from the study include the consistent generation of optimal or near-optimal solutions, the ability to preserve precedence relationships, the superior speed of the algorithm and its practicality due to the ease of implementation in solving disassembly line balancing problems.

2. Literature review

Many authors have discussed the different aspects of product recovery. For a comprehensive