Chapter VI
Lexicographic Goal Programming and Assessment Tools for a Combinatorial Production Problem

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ABSTRACT

NP-complete combinatorial problems often necessitate the use of near-optimal solution techniques including heuristics and metaheuristics. The addition of multiple optimization criteria can further complicate comparison of these solution techniques due to the decision-maker's weighting schema potentially masking search limitations. In addition, many contemporary problems lack quantitative assessment tools, including benchmark data sets. This chapter proposes the use of lexicographic goal programming for use in comparing combinatorial search techniques. These techniques are implemented here using a recently formulated problem from the area of production analysis. The development of a benchmark data set and other assessment tools is demonstrated, and these are then used to compare the performance of a genetic algorithm and an H-K general-purpose heuristic as applied to the production-related application.

INTRODUCTION

More and more manufacturers are acting to recycle and remanufacture their post-consumed products due to new and more rigid environmental legislation, increased public awareness, and extended manufacturer responsibility. A crucial first step is disassembly. Disassembly is defined as the methodical extraction of valuable parts, subassemblies, and materials from discarded products through a series of operations. Recently, disassembly has gained a great deal of attention in the literature due to its role in environmentally conscious manufacturing. A disassembly line 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. These many challenges are reflected in its formulation as a multicriteria decision making problem.

Line balancing (ordering assembly/disassembly tasks on a line to achieve some objective) is critical in minimizing the use of valuable resources (e.g., time and money) invested and in maximizing the level of automation and the quality of parts or materials recovered (Figure 1). The Disassembly Line Balancing Problem (DLBP) seeks a sequence of parts for removal from an end of life product that minimizes the resources for disassembly and maximizes the automation of the process and the quality of the parts or materials recovered. This chapter first mathematically models the multicriteria DLBP, which belongs to the class NP-complete, necessitating use of specialized solution techniques. Combinatorial optimization is an emerging field that combines techniques from applied mathematics, operations research, and computer science to solve optimization problems over discrete structures. Due to the suboptimal nature of these searches, a method is needed to access different combinatorial optimization techniques. Lexicographic goal programming is proposed to provide a hierarchical search structure, while quantitative tools including a benchmark data set are introduced. The DLBP is then solved using two combinatorial optimization methods: a genetic algorithm (GA) and the hunter-killer (H-K) general-purpose heuristic.

LITERATURE REVIEW

Key to addressing any engineering problem is to understand how complex or easy it is, what it shares with similar problems, and appropriate methods to obtain reasonable solutions. For these reasons, a background in optimization and algorithms is valuable. Tovey (2002) provides a well-structured review of complexity, NP-hardness, NP-hardness proofs (including the concise style of Garey & Johnson, 1979), typical NP-hard problems, the techniques of specialization, forcing, padding, and gadgets, mathematical programming versus heuristics, and other complexity classifications. Rosen (1999) provides a useful text in the general area of discrete mathematics including set theory, logic, algorithms, graph theory, counting, set theory and proofs. Papadimitriou and Steiglitz (1998) is the de-facto text on combinatorial optimization as is Garey and Johnson (1979) in the area of NP-completeness. Holland (1975) is credited with developing the genetic algorithm. Osman and Laporte (1996) provide a well-researched paper on all forms of metaheuristics, the basic concepts of each, and references to applications. A follow-on paper by Osman (2004) is more compact and also more current.

A major part of manufacturing and assembly operations, the *assembly line* is a production line where material moves continuously at a uniform rate through a sequence of workstations where assembly work is performed. With research papers going back to the 1950's, the Assembly Line Balancing problem is well defined and fairly well understood. While having significant differences from assembly line balancing, the recent development of DLBP requires that related problems be fully investigated and understood in order to better define DLBP and to obtain guidance in the search for appropriate methodologies to solve it. Gutjahr and Nemhauser (1964) first described a solution to the Assembly Line Balancing problem, while Erel and Gokcen (1964) developed a modified version by allowing for *mixed-model* lines (assembly lines used to assemble different models of the same product). Suresh, Vinod, and Sahu (1996) first presented a genetic algorithm to provide a near-optimal solution to the Assembly Line Balancing problem. *Tabu search* is used in

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