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Book Reviews

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Production planning in automated manufacturing

Springer, Berlin, 1996, ISBN 3-540-61359-5, x + 239 pages, DM 110,-

The introduction of automation in manufacturing has had a substantial impact. In potential, automated manufacturing offers more flexibility, i.e. the ability to respond quickly to changes. Also, it may be possible to have shorter lead times, lower inventories, and higher machine utilization. On the other hand, production planning of automated manufacturing systems using limited resources is complex. The book proposes quantitative approaches for such production planning problems.

In Chapter 2, the authors introduce the problem of maximizing the throughput rate of a line of numerically controlled machines for the placement of electronic components on the surface of printed circuit boards (PCBs). The components are collected on feeders (one component type per feeder) and must be placed into prescribed locations on a PCB. A placement machine has a limited number of feeder slots; each feeder requires one or more adjacent feeder slots. To place components into a board, each placement machine has a moveable arm with three pick-and-place heads. Each head can carry at most one component at a time and it must be equipped with certain tools to handle a component. The authors propose to decompose the planning problem of this system into the following subproblems, which are hierarchically coupled:

(A) determine how many components each machine should insert, and with what equipment;
(B) assign feeder types to machines;
(C) determine which components each head should insert into the board;
(D) cluster the locations into subsets of size at most three, to be processed in one pick-and-place round;
(E) determine the sequence of pick-and-place operations to be performed by each machine;
(F) assign the feeders to the slots.

Most of the subproblems turn out to be NP-hard. For each subproblem, Chapter 2 discusses a solution procedure; the performance of the hierarchical approach is tested on a real-world problem instance.

Chapter 3 deals in more detail with subproblem (D), which is a special case of the three-dimensional assignment (3DA) problem. For subproblem (D), the cost function of 3DA represents the traveling distance of the placement arm. Of course, the traveling distances between locations on a PCB satisfy the triangle inequality. For two cost functions based on traveling distances, the authors show that the resulting 3DA problems are NP-hard and propose ε-approximation algorithms. These algorithms are tested on randomly generated instances.

Chapter 4 discusses a single-machine scheduling problem in which n jobs have to be scheduled within the timespan $[0, T]$. Each job has length p. This machine scheduling problem (SEL) is related to subproblem (F) in which the feeders have to be assigned to slots. SEL is proven to be NP-hard. However, if $T = np + c$, with c a constant, then

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SEL is polynomially solvable. SEL is also studied from a polyhedral point of view.

An overview of tool loading problems that arise in automated manufacturing systems is given in Chapter 5. A basic one-machine problem is identified in which the machine has a limited tool magazine and each job requires certain tools. A *batch* is a set of jobs that can be produced without tool changes in the magazine. In the *batch selection problem*, a batch must be identified that maximizes some criterion function. In the *job grouping problem*, the objective is to partition a job set into a minimal number of batches. In the *tool switching problem*, the objective is to find a job sequence in which the number of required tool changes in the magazine is minimized.

Chapter 6 studies the job grouping problem in detail. An assumption is that each tool requires one slot in the magazine. The authors present a column generation approach to solve the linear relaxation of the set covering formulation of the job grouping problem. Also, heuristics are proposed and tested for the job grouping problem. Chapter 7 discusses a number of extensions of the job grouping problem, e.g. a tool may require more than one slot. The authors show how the upper and lower bounds of Chapter 6 can be adapted to deal with the extensions. Chapter 8 investigates the use of local search approaches (simple improvement, tabu search, simulated annealing, and a variable-depth approach) to improve the solution for the job grouping problem.

Chapter 9 analyzes the tool switching problem. The authors prove that the problem is NP-hard show how the minimum number of setups for a fixed job sequence can be found, and present and test heuristics.

This second, revised and enlarged edition is written clearly. Also, the book discusses interesting practical problems and shows how techniques from operations research may help to analyze and solve them. It requires, however, a solid mathematical background. In my opinion, the title of the book is a little bit misleading. It is not a book about production planning in automated manufacturing, but it discusses only some of the many problems that must be solved for production planning in this environment. Overall I think that researchers with a mathematical background will find this book very interesting.

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Fuzzy set theory and its applications, 3rd edition

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This well-known handbook deserves a third edition. In two parts, it presents a broad introduction to the theory and the applications of fuzzy logic. Part I, Fuzzy Mathematics, 120 pp., consists of 7 chapters which are devoted to the basic concepts: set-theoretic and algorithmic operations, fuzzy measures, the extension principle, fuzzy relations, and fuzzy analysis. Part II, Applications of Fuzzy Set Theory, 280 pp., has also been subdivided into 7 chapters. They are concerned with approximate reasoning, expert systems, control, data analysis, decision analysis, and operations research. The last chapter discusses empirical research on the behavioural foundations of fuzzy logic.

Such a broad overview is risky. Fuzzy logic is an active field of research. Ever since the publication of the seminal paper by Zadeh in 1965, more than 15,000 papers on fuzzy logic have been published (as the author states elsewhere) and each chapter in Part II could easily be expanded into a separate book. The Chapters 9–12 on approximate reasoning, expert systems, control, and data analysis were rewritten for the third edition. Chapter 13 on decision analysis would also benefit from a thorough updating. Nevertheless, these chapters present a concise introduction into particular types of applications, and they do not overload the reader with details.