Complex Sequencing Problems and Local Search Heuristics

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Abstract: Many problems can be formulated as complex sequencing problems. We will present problems in flexible manufacturing that have such a formulation and apply local search methods like iterative improvement, simulated annealing and tabu search to solve these problems. Computational results are reported.

Key Words: Assembling, batching, flexible manufacturing, sequencing problem, simulated annealing, tabu search, tooling.

1. Introduction
Local search heuristics like iterative improvement, simulated annealing, and tabu search are popular procedures for providing solutions for discrete optimization problems. Clearly, a good method should take into account structural properties of the problem. Usually this is accomplished by choosing a neighborhood which is based on specific properties. Also specific organization of tabu list may reflect structural properties of the problem.

In this work we will consider optimization problems which are combinations of a sequencing problem and another type of optimization problem $P$, e.g. partitioning problem or location problem. Therefore, for problems of such type the solution sets consists of all possible combinations of a sequence and a description of a so-
olution of $P$. More precisely, all solutions of the combined problem are given by a set $\{(\pi, r) | \pi \in S_n; r \in R\}$, where $S_n$ is the set of all permutations of a set with $n$ elements and $R$ defines all possible instances of $P$. Denote by $f(\pi, r)$ the corresponding objective value. For our approach to solve such combined problems we will consider only the set of sequences as solutions. For a given sequence $\pi$ we solve the optimization problem $\min\{f(\pi, r) | r \in R\}$ and do local search on the set of sequences. The corresponding optimization problems are solved by polynomial algorithms or sophisticated heuristics that take into account structural properties of the problem. This approach reduces the cardinality of the search space drastically. Furthermore, it is possible to choose relatively easy and general neighborhoods for the local search on the set of sequences since structural properties are already incorporated in the solution of the optimization problem. The prize for this advantage is a more complex objective value for a given solution (sequence).

In Section 2 we will give a formal definition of complex sequencing problems and describe the specific methods we used to solve these problems. We apply these methods to bin location and assembly sequencing (Section 3), switching tools on a flexible machine (Section 4), and batching problems (Section 5). Computational results show that these methods yield very good results.

2. Complex Sequencing Problems

A complex sequencing problem may be formulated as follows. Let $X$ be a subset of all permutations of a finite set. Associated with each permutation $\pi$ in $X$ there is an optimization problem $OPT(\pi)$. Let $f(\pi)$ be the optimal solution value of $OPT(\pi)$. Find a permutation $\pi^*$ which optimizes $f$ over all permutations in $X$. Usually $OPT(\pi)$ is a problem which can be solved efficiently (e.g. a linear program, a shortest path problem, etc.)

To solve complex sequencing problems different local search heuristics are considered. To apply these heuristics to a specific problem, an appropriate neighborhood structure on $X$ has to be defined. As mentioned in the introduction, we consider simple neighborhood structures which are given by operator sets $OP(\pi)$ defined for permutations $\pi$. An operator $op \in OP(\pi)$ associates with the permutation $\pi$ a new permutation $op(\pi)$. $\{op(\pi) | op \in OP(\pi)\}$ is called