4. Fuzzy Scheduling

4.1 Introduction

Scheduling has become a very important field in production and operations management. Due to the fact, that mathematical-analytical methods developed in the context of operations research have limitations with regard to the complexity of real world applications, knowledge based methods representing the restrictions and problems of an application explicitly by the use of constraints have been developed. Theoretical scheduling problems, concerned with searching for optimal schedules subject to a set of constraints suffer from excessive combinatorial complexity. However, it is possible to find a compromise between efficiency and exactness of a schedule by relaxing some criteria. Another path leading to less complexity is simplifying the model to the main characteristics of a scheduling problem, what is sufficient for most real-world-applications. Of course, the search space and complexity can not be reduced arbitrarily. In this sense, we would like to find an algorithm that intelligently ‘guesses’ good schedules by the use of heuristic methods. Generally speaking, classical operation research methods yield optimal solutions, if they exist, though they might fail when a problems complexity is nearly NP-hard, i.e., their execution time grows more than polynomially when structure parameters grow linearly. In contrast to this, most knowledge based approaches do not guarantee to find an optimal solution, but they provide other important features: the knowledge base and the inference mechanism are separated and can be manipulated separately, heuristics yield solutions that in most cases are very close to the optimum, and they provide the ‘anytime’-feature: we can specify a deadline for the heuristic within a solution, even if not the best one, has to be delivered.

4.2 Definition and Classification of Scheduling Problems

[Baker74] defines scheduling as follows:

> „Scheduling is the allocation of resources
> over time to perform a collection of tasks“

Scheduling is usually described as an activity controlled by constraints and guided by several objective functions. Scheduling problems form a class of discrete optimization problems which very often occur in production and production planning, but also in other sectors. They are concerned with assigning a given set of machines/processors and possibly other resources to a set of tasks in order to execute the tasks optimally subject to certain constraints, such as deadlines, availability of resources, priorities for some tasks over others or machine capabilities.

Typical scheduling problems can be found in the fields of transportation, production and maintenance, manpower planning and time-tabling, project or mission scheduling, network planning and routing, computer or printer job scheduling, etc. The following table should illustrate the complexity of scheduling:

ACTIVITIES	– interval (block) activities – splittable activities (with interruption cost?)
RESOURCES	– unary resources – discrete resources – state resources – energetic resources
CONSTRAINTS	– temporal constraints – resource constraints – specific constraints
OPTIMIZATION CRITERIA	– no optimization criterion – a well defined criterion – a combination of well defined criteria – preferences (soft constraints) – optimization vs. robustness
PROBLEM SIZE	– number of activities, resources, ...
TIME AVAILABLE TO MAKE A DECISION	– suitable response time

Table 4.1: Scheduling components

This classification is a generalization of scheduling tasks. To illustrate variations in problem types, we examine a manufacturing domain: a job is an item or batch of items that require processing on some machine (resource). The processing of a particular job is called activity. Such a job may have a release and a due date. Associated with each resource is some formal specification of its characteristics and capabilities. The processing may require one or more different resources, some of them consumable, others not. The goal is to find the optimal schedule with respect to some optimization criterion, such as minimizing the schedule length (makespan), the mean flow time or the maximum lateness. In this sense we distinguish three different types of scheduling problems:

- ❑ *general job shop scheduling:* every job may have a different sequence of activities that are assigned start and end times, where each activity requires given resources with given capacities

- ❑ *flow shop scheduling:* every job has the same sequence of activities and allocated resources

- ❑ *permutation scheduling:* the same job-sequence applies to all activities and resources.

Most current approaches to automated scheduling organize problem solving into two components, a decision making component responsible for choosing amongst scheduling decisions in order to reach a good schedule, and a constraint management component.

In the next section we will present a steelmaking scheduling problem and investigate how schedules can be generated using fuzzy constraints and heuristic search methods. The motivation for the introduction of a fuzzy constraint representation are mainly three different types of imprecision. One the one hand many real-world scheduling tasks have to handle constraints that are blurred in definition and that might be redefined as fuzzy constraints. Another source of imprecision arises from ill defined preferences between possible alternatives. Finally, uncertainty about values of certain scheduling parameters is an additional aspect of imprecision. In Chapter 3 we have seen how these different types of imprecision can be handled by the use of fuzzy constraints, linguistic terms, and appropriate weighting schemes.