Heuristic Optimization in Production Planning

Project Focus

- Special area of production planning:
  Sequencing & Scheduling in a job-shop manufacturing environment
- Sequencing =
  Determine processing order of production operations on one or more machines
- Scheduling =
  Determine start and end dates for production operations (-> Schedule)
- Role of Optimization:
  Find the best possible schedule w.r.t. a given objective function

Motivation

- Manufacturing companies
  - face increasing amount of customer orders
  - want to fulfill orders without increasing manpower / existing capacities
- Accurate decision-making is necessary
- Complex problems difficult to handle for human experts

-> Effective production management highly depends on (optimization) software support

Theory: One-Machine Scheduling

- Given: Jobs / Operations with predefined
  - Processing Times
  - Release Dates
  - Due Dates
  - Weights
- Constraints:
  - No preemption
  - Disjunction
- Typical objectives:
  - (Weighted) Tardiness
  - Completion Times (Flow Time)

Solution Methodology

- Exact solution approaches:
  - Mainly Branch & Bound
  - Limited to 40 jobs / operations on one machine
- Heuristic methods:
  - Neighborhood based:
    - Tabu Search
    - Iterated Local Search / Large Step Optimization
  - Population based:
    - Genetic Algorithms
    - Ant Colony Optimization

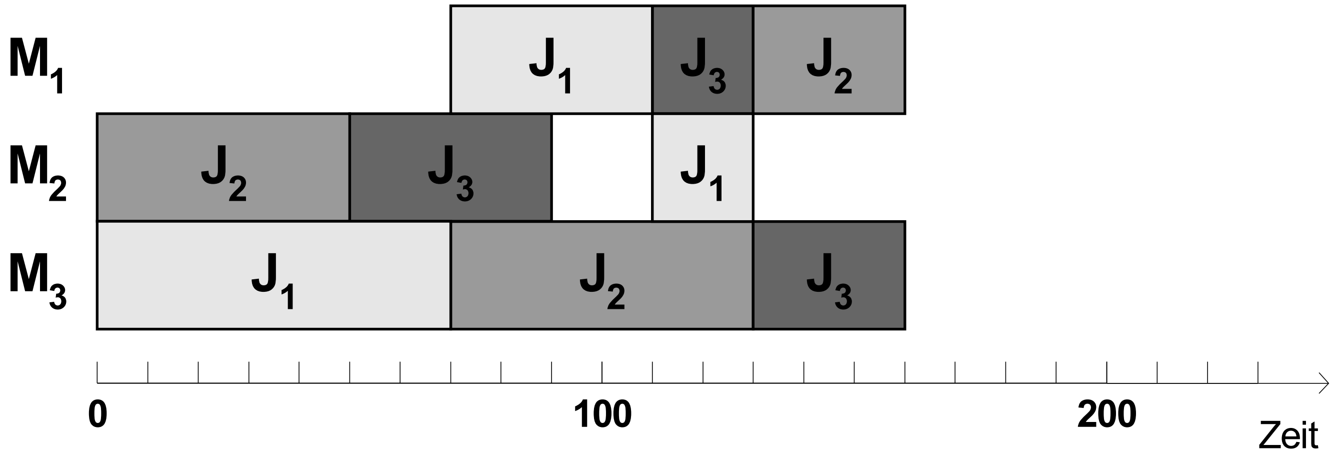
Theory: Multi-machine Scheduling

- Classic Job Shop Scheduling Problem
- Multi-stage environment:
  - Jobs consist of multiple operations
  - Operations are processed on different machines
  - Sequence of operations (routing) is predetermined
- Problem setup similar to one-machine scheduling; furthermore:
  - Operations can have different processing times
  - Technological constraints (routing)

Theory: Multi-machine Scheduling

- Example (3 Jobs / 3 Machines)

	1	2	3
Job 1	M_3 (70)	M_1 (40)	M_2 (20)
Job 2	M_2 (50)	M_3 (60)	M_1 (30)
Job 3	M_2 (40)	M_1 (20)	M_3 (30)



Common Optimization Objectives

- Makespan
- Tardiness-related
  - Total (weighted) tardiness
  - Maximum Lateness / Tardiness
  - Earliness/Tardiness
- Flow Time
- Machine Utilization

Solution Methodology

- In general: Effectiveness and computation time depend on objective function
- Exact methods
  - High computational effort
  - Limited to small problems (up to 20x20)
- Heuristics
  - Genetic Algorithms
  - Tabu Search
  - Decomposition Approaches
    - Bottleneck-based Scheduling

Real-world Scenarios:

- Transfer of concepts and methods from theory can be difficult
- Obstacles / differences to abstract theory:
  - Multi-level job structures
  - Material requirements
  - „Real“ machine capacities
  - Parallel flow structures
  - Operation overlap
  - External processing
  - Problem dimension (100-400 vs. 10000-30000 ops.)

Project Status

- First results for single-machine scenario
- Consideration of
  - Machine capacities
  - Material requirements
  - Backlog
  - Precedence constraints
- Tardiness-related measures
  - Total weighted tardiness
  - Number of late jobs

Solution Approach

- Simple Tabu Search algorithm
- Neighborhood concept:
  - Interchange of operations
  - Limited, randomly determined neighborhood
- Small computation times (<5min.) even for large instances (up to 500 jobs)
- Comparison with priority dispatch rules
  - Earliest Due Date, ...
  - Improvements up to 50%

Concepts for the Multi-machine Case

- Decomposition / Bottleneck-based scheduling
  1. Split problem into single machine problems
  2. Determine bottleneck machine
  3. Optimize bottleneck machine
  4. Fix sequence on bottleneck machine
  5. Repeat steps 2 to 4 until all machines scheduled
- Neighborhood-based search
  - Graph model
  - Perform potentially profitable interchanges of operation on the same machine