Tuesday, August 30, 14:00, Room MA309

A Lagrangian Relaxation Method for the Minimum Completion Time Variance Scheduling Problem

Jose Ventura, The Pennsylvania State University

In this presentation, the problem of minimizing the completion time variance in n-job, single-machine scheduling is considered. The release times for all jobs are assumed to be zero. A new quadratic integer programming formulation is introduced. A Lagrangian relaxation (LR) procedure is developed to find a lower bound to the optimal objective value. When the number of jobs is between 100 and 500, our computational study shows that the lower bounds obtained by the LR procedure are, on the average, 0.011known objective values. A new (two-phase) heuristic algorithm is also proposed. The first phase of the heuristic algorithm is a construction procedure whose purpose is to identify a good initial sequence. The second phase is an improvement procedure based on pairwise interchanges. The new heuristic algorithm provides improved solutions compared to the best known heuristic.

Tuesday, August 30, 14:00, Room MA043

On the Pipeless Chemical Plants

Ferenc Katai, Tokyo Institute of Technology
Masaru Ishida, Tokyo Institute of Technology

Some years ago the brilliant idea of pipeless chemical plant emerged. In such a plant the reactors are movable robots and there are some so-called stations which can supply the materials and play the role of stores. Let us suppose there is a set of stations, robots and some recipes of products. Every recipe is matched to a robot and every robot has a deadline. The plant looks flexible however by now the robots has been cotrolled by a big computer, thus it remains static. Since changes frequently emerge (canceled products, changed deadlines, etc.) a prescribed scheduling in case of changed conditions might become improper. In addition the centralized control is expensive as well. Our main goal is at least two-folded. In a changing environment the scheduling must be changed dynamically and the plant should be cheaper than a "traditionalöne. On this way a distributed approach has been proposed in which every robot knows only its deadline and recipe working on its own and a scheduling is built up evolutionary based on some policies. By means of several sort of stochastic policies either schedule(s) can be made before the system starts working or using the deterministic policies it can be controlled when it is working. The method is fairly fast. However, in case of improper deadlines sometimes there is no solution. The disadvantage is that an exact answer has not been given if any solution exists. Making statistics of the evolved schedules can bridge the problem what the proper deadlines are can be guessed.

Tuesday, August 30, 14:30, Room MA309

Solving Scheduling Problems with Mathematical Programming and Constraint Logic Programming

Wouter Blondeel, Beyers & Partners

During this presentation it is shown how scheduling problems can be solved with mathematical programming techniques (MP) and constraint logic programming (CLP).

Firstly, a short review is provided on MP and CLP techniques. Next, it is indicated which types of scheduling problems are suitable to be solved with these techniques.

Finally, a short desciption of several industrial applications is provided. These applications have been developed with OMP (MP package) and CHIP (CLP tool).

Tuesday, August 30, 14:30, Room MA043

Office Scheduling

Günter Schmidt, Universität des Saarlandes, Saarbrücken
Jörg Winckler, Universität des Saarlandes, Saarbrücken

Although in the past many users have made strong effort in office communication the productivity in office did not increase as much as expected. Reasons are (among others)

- The systems are intented to improve the effectivity and the efficiency of the individual employee.
- An integrated process-oriented flow of work is not supported.

Groupware- and Workflow-systems should overcome these deficiencies. We investigated how models of the scheduling theory can be used to support business processes. We show that scheduling models can be used in workflow systems especially to support well structured processes.

Tuesday, August 30, 15:00, Room MA309

A Cutting Plane Approach for the Job-Shop-Scheduling Problem

Thomas Latz, Universität des Saarlandes

The job-shop scheduling problem is often discussed in combinatorial optimization. A lot of good heuristics are known like the work by Adams et al., Carlier & Pinson, Applegate & Cook and Brucker et al. These heuristics compute fast upper bounds but the problem remains to find good lower bounds to prove a solution as optimal. For example the solution of the notorious 10×10 problem from Muth & Thompson was found by Carlier & Pinson in short time while the proof of optimality tooks long time.

Applegate & Cook proposed some cuts for a cutting plane approach but came to the result "that it remains a research challenge to find classes of valid inequalities that will close the large gap between the lower bound values and the optimal value of scheduling problems, within a reasonable amount of computation time".

Brucker, Jurisch and Krämer discussed several selection strategies to direct edges in the disjunctive graph model of Balas. These selection strategies help to simplify the problem during the optimization process.

This talk combines the branch and cut concept – also with new cutting planes – with the selection strategies to find good lower bounds.

Tuesday, August 30, 15:00, Room MA043

Modellierung von Verwaltungsabläufen

Brigitte Werners, Ruhr-Universität Bochum

In diesem Beitrag erfolgt eine Darstellung und Diskussion von Modellklassen, die für eine Abbildung von Verwaltungsabläufen geeignet sind. Dabei wird insbesondere berücksichtigt, welche Möglichkeiten der Analyse und Optimierung der Verwaltungsabläufe durch diese Modellklassen und die dort einsetzbaren Algorithmen gegeben sind. Dies bildet die Grundlage für eine Verbesserung von Verwaltungsprozessen.

Tuesday, August 30, 15:30, Room MA309

Single Machine Batch Scheduling to Minimize the Total Weighted Late Work

Peter Brucker, Universität Osnabrück
Mikhail Kovalyov, Institute of Engineering Cybernetics, Minsk

The single machine batch scheduling problem to minimize the weighted number of late jobs is studied. In this problem, n jobs have to be processed on a single machine. Each job has a processing time, a due date and a weight. Jobs may be combined to form batches containing contiguously scheduled jobs. For each batch, a constant set-up time is needed before the first job of this batch is processed. The completion time of each job in the batch coincises with completion time of the last job in this batch. A job is late if it is completed after its due date. A schedule specifies the sequence of jobs and the size of each batch, i.e. the number of jobs it contains. The objective is to find a schedule which minimizes the weighted number of late jobs.

We show that this problem is NP-hard for any positive set-up time and equal due dates and present a dynamic programming algorithm. We formulate a certain rescaled problem and show that our dynamic programming algorithm applied for this rescaled problem provides a fully polynomial approximation scheme for the original problem. Each algorithm of this scheme has a time requirement of $O(n^3/\epsilon + n^3 \log n)$.

A side result is an $O(nlogn)$ algorithm for the problem of minimizing the maximum weight of late jobs.

Tuesday, August 30, 15:30, Room MA043

Optimization of the Placement-Time on a Circuit Board

Steffen Meusel, TU Bergakademie Freiberg

Consider a machine for placing several components of different types from fixed storage areas into predefined places on a circuit board. In general, minimizing the placement-time leads to a Traveling Salesman Problem (TSP), which requires NP-complete algorithms. Due to the structure of this particular problem, which involves visiting the same storage several times, we can simplify our problem into a Transportation Problem (TP) with two groups of additional constraints:

1. constraints to prevent subtours with only one component type,
2. constraints to prevent general subtours.

The advantage of this partition is the unimodularity of the first group of constraints, which allows one to integrate them into the TP and solve it in polynomial time. This approach leads in nearly all cases to subtour-free solutions, so the second constraints (which lead to non-polynomial algorithms) have to be considered only seldom.

The algorithm for the problem is written in C++.
Further investigation might cover nonfixed component-storage areas.

Wednesday, August 31, 10:00, Room MA043

An Approach to Multiple Criteria Decision Making in Production Scheduling

Karl Frauendorfer, Hochschule St. Gallen
Emil Königsperger, Hochschule St. Gallen

A MCDM method for supporting production scheduling decisions is proposed. Special attention is devoted to the fact that some of the data necessary for evaluation is difficult to obtain, and production managers often find it difficult to utter their preferences. One distinctive element of the method is that the different information content of attributes is taken into account by attribute classification. Attributes with known cost relevance are separated from attributes with not explicitly known cost relevance. Preference information for non-cost attributes is elicited via substitution assessments. Cost effects are related to the non-cost effects of substitution violations and presented to the user for further preference input. User preferences are tested for consistency in a linear program, which allows for the representation of non-cost attributes as value functions as well. Value functions of both attribute classes are modelled as linear-quadratic mappings.

Wednesday, August 31, 10:30, Room MA043

Production Scheduling and Neural Networks

Wen-Jia Wang, UMIST Manchester
Paul Brunn, UMIST Manchester

This paper considers the application of neural networks for production scheduling problems. It reviews and analyses the difficulties and approaches to the production scheduling problem, then describes the features of neural networks and the reasons for applying them for scheduling problems. Furthermore it presents the general methods and steps for the mapping the production scheduling problem onto a neural network and then discusses specific scheduling examples from the Author's research.

Wednesday, August 31, 14:00, Room MA043

Heuristics for Resource-Constrained Project Scheduling with Minimal and Maximal Time Lags

Klaus Neumann, Universität Karlsruhe

Heuristics for two types of resource-constrained project-scheduling problems are presented: the minimum project-duration problem and the problem of levelling the resources' consumption. Both minimal and maximal time lags between the start of successive activities of the project in question are permitted, which can be modelled by an activity-on-node network containing cycles (*MPM-type network*). Maximal time lags or respectively cyclic MPM networks make resource-constrained project scheduling problems pretty complicated. In constrast to acyclic networks which only allow for minimal time lags, even the problem of finding a feasible solution is in general NP-hard. To solve the minimum project-duration problem for MPM networks approximately, three different types of heuristics are presented. In the *direct methods*, the activities are at first ordered appropriately and then scheduled in that order. Here "truncated" versions of the branch-and-bound methods for acyclic networks (without backtracking steps) generalized to cyclic networks are used. The *contraction methods* regard each strong component of the network as a separated partial project and construct a feasible subschedule for the latter project. Thereafter, each strong component is replaced by a single activity, which results in an acyclic network. Thirdly, the *priority-rule methods* for acyclic networks are generalized for cyclic networks. The direct and constraction methods can also be modified to solve problems of levelling the resources' consumption approximately.

Wednesday, August 31, 14:30, Room MA043

Discrete-Continous Scheduling Heuristics and Their Worst-Case Analysis

Joanna Józefowska, Technical University of Poznan, Poland
Jan Węglarz, Technical University of Poznan, Poland

We consider problems of scheduling nonpreemptible jobs on m parallel machines to minimize makespan when each job requires for its processing a machine and an amount (arbitrary within a given interval) of a continuous (i.e. continuously-divisible) resource. Each job is characterized by a continuous, nondecreasing function relating job processing rate to the resource amount allotted to this job at a time. The beginning (equal to zero) and the final states of job are also known. We propose different approximation algorithms for the considered class of scheduling problems. For some special cases the results of the worst-case analysis of these algorithms are also presented.

Wednesday, August 31, 15:00, Room MA043

Improving Local Search Heuristics for some Scheduling Problems

Peter Brucker, Universität Osnabrück
Johann Hurink, Universität Osnabrück
Frank Werner, Universität Magdeburg

In this paper we consider certain NP–hard scheduling problems. Problems of this type can be solved either by exact methods like branch and bound or dynamic programming or by heuristic methods. Popular heuristics are local search methods like simulated annealing and tabu search. These methods depend on an underlying neighborhood structure. Usually, the quality of the neighborhood structure has some important influence on the methods.

For the scheduling problems $Pm \mid\mid C_{max}$, $1 \mid\mid \sum \tau_i$, $1 \mid prec \mid \sum U_i$, and a large class of sequencing problems with precedence constraints having local interchange properties we replace a simple neighborhood by a neighborhood on the set of all locally optimal solutions. This allows local search on the set of solutions that are locally optimal. Computational results are presented.

Wednesday, August 31, 15:30, Room MA043

Heuristics for Permutation Flow Shop Scheduling with Batch Setup Times

Yuri Sotskov, The Byelorussian Academy of Sciences
Thomas Tautenhahn, Otto-von-Guericke-Universität Magdeburg
Frank Werner, Otto-von-Guericke-Universität Magdeburg

In this paper we consider permutation flow shop scheduling problems with batching. Each job has to be processed on each machine once and in the same order. The set of n jobs is divided into k groups. There are given processing times t_{ij} of job i on machine j and setup times s_{rj} on machine j when a job of the r-th group is processed after a job of another group. The set of feasible schedules is restricted by schedules with the same job order on each machine. The objective is to minimize the makespan or the sum of completion times with batch or item availability. For these problems we give various constructive and iterative algorithms. The constructive algorithms are based on insertion techniques combined with beam search. Moreover we give iterative algorithms that are based on local search and reinsertion techniques. We introduce suitable neighbourhood structures for such batching problems. For evaluating the quality of our algorithms we also derive lower bounds for the problems being considered. The developed algorithms have been tested on a large collection of problems with up to 80 jobs.

Wednesday, August 31, 16:30, Room MA043

Scheduling Jobs in Shops with Multi-Purpose Machines

Bernd Jurisch, Universität Osnabrück

In shop scheduling problems with multi-purpose machines we have a set of jobs, each one consisting of a number of operations. Moreover there is a set of multi-purpose machines, each one equipped with different tools. Associated with each operation there is a set of machines which due to their tool equipment can process this operation. The processing of an operation takes a given amount of time. We have to find an assignment of the operations to the machines and a schedule for the operations on the machines such that a given objective function is minimized.

We will present different solution methods for the job-shop problem on multi-purpose machines:

- a branch and bound algorithm;
- methods for calculating lower bounds;
- algorithms for calculating good heuristic solutions based on priority rules or neighborhood search.

Finally, we present computational results obtained by running the given programs on benchmark problems.

Wednesday, August 31, 17:00, Room MA043

Variants of the Two Machine Flow Shop Problem

Leo G. Kroon, Erasmus University Rotterdam
Harm Bart, Erasmus University Rotterdam

In this presentation a number of variants of the Two Machine Flow Shop Problem (2MFSP) are considered. In these problems the makespan is given and the problem is to find a schedule that meets this makespan, thereby minimizing the infeasibilities of the jobs in some sense: in the first problem (2MFSP-M) the maximum infeasibility of the jobs is to be minimized, whereas in the second problem (2MFSP-T) the objective is to minimize the sum of the infeasibilities of the jobs.

For both problems observations about the structure of the optimal schedules are presented. In particular, it is shown that every instance of these problems has an optimal permutation schedule. It is also shown that 2MFSP-M can be solved by Johnson's Rule. For 2MFSP-T this is not the case. There are indications that for solving 2MFSP-T something quite different is needed.

Both 2MFSP-M and 2MFSP-T can be applied in Systems Theory to find minimal factorizations of companion based matrix functions that are optimal in some sense.

Wednesday, August 31, 17:30, Room MA043

Scheduling a flow shop to minimize maximal lateness under precedence constraints

Joanna Józefowska, Poznań University of Technology

An m-machine flow shop is considered. It consists of m stages, one machine on each stage. Every task $T_i(i = 1, \ldots, n)$ consists of a sequence of m operations. Operation $j(j = 1, ..m)$ has to be completed on machine i. Moreover precedence constraints between tasks are allowed. Task T_i precedes task T_j ($T_i \prec T_j$) means that the last operation on task T_i has to be completed before the first operation on task T_j can start. Precedence constraints are represented by an arbitrary acyclic directed graph G with nodes reprezenting tasks. Every task has to be completed by a given due date d_i. The problem is to find a schedule minimizing the maximum lateness i.e. $max(C_i - d_i)$, where C_i denotes the completion time of task T_i .

Firstly the case of two machines and unit processing times is considered. For this case a polynomial time optimization algortihm is presented. Assuming arbitrary processing times or three machines NP-hard problems are obtained. Some heuristics have been developed for these problems and evaluated on the basis of a computational experiment.

Wednesday, August 31, 18:00, Room MA043

Batch Scheduling in a Two Machine Flow Shop with Limited Buffer

Alessandro Agnetis, Universita' di Roma "La Sapienza"
Dario Pacciarelli, Universita' di Roma "La Sapienza"
Fabrizio Rossi, Universita' di Roma "La Sapienza"

This talk deals with the problem of makespan minimization in a flow shop with two machines when the input buffer of the second machine can only host a limited number b of parts. This problem has been shown to be NP-hard for any $b > 0$ and $b < n$, where n is the number of jobs, by Papadimitriou and Kanellakis (1980). Here we analyze the problem in the context of *batch processing*, i.e., when parts of the same type must be processed consecutively. Each set of identical parts forms a *batch*. The number of identical parts in the batch is the *size* of the batch. We first prove that, if the size of the i-th batch is at least h_i^* for all i, then the makespan minimization problem can be formulated as a special case of TSP and solved in polynomial time. The cost structure of this TSP generalizes the one defined for the two machine no-wait flow shop, i.e., when b=0. Hence, we give a closed form expression for h_i^*. Finally, we give an ϵ - approximation algorithm for the general case, in which the error goes to zero as the batch sizes approach the values h_i^*.

Thursday, September 1, 09:00, Room MA043

Exact and Heuristic Algorithms for the Jump Number Problem

Lucio Bianco, Univ. of Rome "Tor Vergata", I.A.S.I. - C.N.R.
Paolo Dell'Olmo, Univ. of Rome "Tor Vergata", I.A.S.I. - C.N.R.
Stefano Giordani, Univ. of Rome "Tor Vergata", I.A.S.I. - C.N.R.

Given a partially ordered set $P = (V, <_P)$ (also called partial order or poset) a linear extension $L = (V, <_L)$ of P is a total order on the same ground set V of P, such that each couple of element $u, v \in V$ for which

$u <_P v$ implies $u <_L v$. Given two consecutive elements $u, v \in L$ the couple (u, v) forms a *jump* or *setup* if u, v are not comparable in P. The *jump number problem* of P consists in determining a linear extension L of P with minimum number of jumps. It arises, for example, from scheduling problems where n tasks, subject to precedence constraints given by a partial ordering, are to be processed on a single processor, where a processor setup unit cost is occurred when the processor switches from one task to another which is not constrained to precede it; the problem consists in finding a schedule with minimum setup number. We present an exact algorithm based on dynamic programming and a heuristic algorithm for the jump number problem for general posets. The algorithms have been experimentally evaluated on a set of randomly generated posets of different size and different density. Concerning the heuristic algorithm we have seen that it has produced optimal solutions for a large set of test problems and in the worst case the relative error was not greater than 0.2. Regarding the dynamic programming algorithm the number of states generated and the time spent by it are strictly related to the relative gap $\frac{UB-LB}{LB}$.

Thursday, September 1, 09:00, Room MA309

Models for Scheduling and Batching with Deadlines

Carsten Jordan, Christian - Albrechts - Universität zu Kiel
Andreas Drexl, Christian - Albrechts - Universität zu Kiel

In the first part we analyze what batching means and present a classification of different batching types. We focus on the case where the set of jobs is partitioned into families, and sequence dependent setups occur between families. Very “hardproblems arise if jobs in one family have different deadlines and families must further be partitioned into batches. We analyze the batching types for this case and discuss how those models correspond to lotsizing and scheduling models, e.g. the Discrete Lotsizing and Scheduling Problem (DLSP). In the second part we present some exact and heuristic methods for the above models. Essentially the scheduling problem consists of strongly interdependent batching and sequencing decisions. We provide some comparisons with other procedures from literature and show how our approaches favourably compares.

Thursday, September 1, 09:30, Room MA043

A Parallel Based Algorithm for an EMS Model

Markus Helmuth Salchegger, University of Salzburg, Austria

The paper is devoted to a short-term hydro unit calculation problem. A standard model for the system is presented. Because of the high requirements on the computation speed and memory in practical problems usually one makes use of heuristic methods with only limited mathematical accuracy.

Our contribution here is to indicate a method and an algorithm to overcome this difficulties. We build a dynamic programming based algorithm combined with coarse grain parallelism. We will show

- a standard model,
- an efficient algorithm based on Bellman's principle,
- coarse grain parallelism,
- estimations concering the (parallel) complexity, speed up and efficiency,

Thursday, September 1, 09:30, Room MA309

Komplexität des diskreten simultanen Losgrößen- und Reihenfolgeproblems

Wolfgang Brüggemann, Universität Hamburg
Hermann Jahnke, Universität der Bundeswehr Hamburg

Das diskrete simultane Losgrößen- und Reihenfolgeproblem (Discrete Lotsizing and Scheduling Problem, DLSP) kann zur Planung der intermittierenden Fertigung mehrerer Produkte auf einer Maschine bei deterministisch dynamischer Nachfrage und endlichen Produktionsgeschwindigkeiten eingesetzt werden. Dabei wird unterstellt, daß während einer Periode die Maschine nur für höchstens eine Aktivität (Produktion einer Sorte oder Rüstung für eine solche Produktion) zur Verfügung steht. Nach einem kurzen Überblick über mögliche komplexitätstheoretische Aussagen und Beweistechniken werden aus der Literatur bekannte Resultate dieser Theorie für das DLSP kritisch betrachtet. Als problematisch für solche Aussagen stellt sich heraus, daß bekannte Modellformulierungen des DLSP in einem zu spezifizierenden Sinn nicht minimal sind. Abschließend wird gezeigt, daß das DLSP als Optimierungsproblem in Abhängigkeit von der gewählten Datendarstellung mindestens streng NP-schwer ist. Dieses Resultat läßt sich auch auf den Fall geschlossener Fertigung erweitern.

Semi-Plenary Lecture

Thursday, September 1, 11:30, Room MA043

Two, Three, Many or the Complexity of Scheduling with Fixed Number of Jobs

Yuri Sotskov, Academy of Sciences of Belarus, Minsk

The lecture surveys the complexity results for the shop-scheduling problems under assumption that the number of jobs n is less or equal to the number of machines m; $n \leq m$. The job-shop, flow-shop and open-shop scheduling problems with *two jobs* can be solved in polynomial time for any given regular criterion. On the other hand, the shop-scheduling problems with *three jobs* are binary $\mathcal{NP}$-hard even in the case of rather simple criteria; $C_{\max}$ and $\sum C_i$ (the only exception is an open-shop problem with criterion $C_{\max}$ and allowed operation preemptions, which is polynomially solvable for any n and m). Owing to the reducibility among the scheduling problems with different criteria, we can conclude that the shop-scheduling problems with *three jobs* are binary $\mathcal{NP}$-hard for any given non-trivial regular criterion (with only the one above exception). It should be noted that a shop-scheduling problem with *fixed number of jobs* is not unary $\mathcal{NP}$-hard since for each fixed number of jobs, job-shop scheduling problem can be solved pseudopolynomially.

For a mixed-shop scheduling problem with *two jobs* (when one job has fixed route and other job has non-fixed route), the polynomial-time algorithm exists for any given regular criterion in the case of preemption allowance. If operation preemptions are forbidden, mixed-shop scheduling problem with *two jobs* is binary $\mathcal{NP}$-hard even for criteria $C_{\max}$ and $\sum C_i$

Thursday, September 1, 14:00, Room MA043

The ADLIPS Algorithm and Data Library for Project Scheduling

Rolf H. Möhring, Technische Universität Berlin
Rudolf Müller, Humboldt Universität zu Berlin

ADLIPS is a library of data structures and algorithms for project scheduling It is based on the software engineering environment YPSILON, which was developed along the ADLIPS project. ADLIPS provides algorithms for stochastic PERT network evaluation, time-cost trade-off problems, machine-scheduling and resource constrained scheduling problems with generalized time-windows.
The talk gives an overview on the functionalities of ADLIPS, it addresses the experiences made in implementing a large algorithm and data library, and it shows how these experiences guided the design of YPSILON. In particular it shows how combinatorial structures integrated in ADLIPS are used to build *Eigenmodels*, e.g., data flow graphs, of the ADLIPS library.

Thursday, September 1, 14:30, Room MA043

A New Kind of Algorithm for the Partitioning Problem

Hans Kellerer, Universität Graz, Austria
Vladimir Kotov, Byelorussian State University Minsk

For a given list of n items with positive weights we look for a partition into m subsets in order to minimize the makespan. We propose an algorithm which is a mixture of the LPT–algorithm and the Multifit–algorithm. Our heuristic determines parameters k and level. At each step it looks through sets according to the current weight (from the largest to the smallest one) and reduces subsets with possible total weight from the interval [level, level + k ∗ level]. Here, the posssible total weight denotes the sum of the current weight of a set and the total weight of some current items. In case there is no reduction the algorithm looks like the LPT–algorithm.

We investigate the worst–case performance of this algorithm.

Thursday, September 1, 15:00, Room MA043

Maximizing the Minimum Completion Time on a Multiprocessorscheduling System

Hans Kellerer, Universität Graz
Vladimir Kotov, Byelorussian State University Minsk

Maximizing the minimum completion on m identical machines is quite similar to the classical problem of minimizing the makespan. Proving worst–case bounds for approximation algorithms is quite difficult compared to the usual case, since the "small" jobs cannot be neglected. We present several heuristics where we especially mention the necessary proof techniques to show reasonable worst–case bounds for such kind of problems. The case of machine release times is also considered. Finally, something is said about other maxmin criteria for scheduling problems.

Thursday, September 1, 15:30, Room MA043

Asymptotically Exact Approach to the Solution of Bin Packing Problem

Edward Gimadi, Institute of Mathematics at Novosibirsk, Russia

We consider the following one-dimensional Bin Packing Problem: a list S of integer numbers (items) a_i, $i = 1, ..., n$, in the range $(0, B]$ is to be packed into a minimal number of bins, each of which holds a total of the most B, when B – integer. Numbers a_i are assumed to be independent random variables with the identical discrete distribution $P = \{p_k |\ k = 1, ..., B\}$.

For a list S, let $F_A(S)$ denote the number od bins used by algorithm A and let $F^*(S)$ denote the minimal number of bins into which S can be packed.

There are obtained the estimates of following kind:

$$Pr\{F_A(S) > (1 + \varepsilon_n)F^*(S)\} \leq \delta_n.$$

We describe the approximation polynomial algorithm A and prove the conditions of asymptotical exactness (i.e. when the estimates $\varepsilon_n \to 0$, $\delta_n \to 0$ as $n \to \infty$) for the proposed algorithm for some distributions.

For example, we show that if P is B – asymmetric distribution, the algorithm has estimates

$$\varepsilon_n = c_1\sqrt{\frac{B\ ln\ n}{n}}, \qquad \delta_n = c_2 B/n^2$$

(c_1, c_2 – positive constants), hense algorithm is asymptotically exact when $B = o(n/ln\ n)$.

The similar results are obtained in the case so-called B-regular distribution (i.e. P can be represented as the sum of 2^i-symmetrical functions, where $i = 1,,,,Q$, $Q = log_2 B$). In particular, decreasing distribution is B-regular, if $B = 2^Q$.

Friday, September 2, 10:30, Room MA309

Ein analytisches Verfahren der stochastischen Zeitplanung in Vorgangsknotennetzen

Uwe Clasen, Universität Rostock

Das Projektmanagement muß heute unter den Bedingungen des internationalen Zeitwettbewerbs dem Faktor Zeit stärkere Beachtung widmen. Deshalb werden solche Verfahren und Methoden zur Planung, Überwachung und Steuerung von Projekten benötigt, die es gestatten, das zeitliche Risiko rechtzeitig und zuverlässig zu beurteilen, und dadurch einen termingerechten Projektabschluß unterstützen. Die gegenwärtig weit verbreiteten Verfahren der deterministischen Netzplantechnik werden diesem Anspruch jedoch nicht in vollem Maße gerecht. Ein vertrauenswürdiges stochastisches Zeitplanungsverfahren entsteht, wenn zur Beschreibung der Vorgangsdauern und Projektzeitpunkte der flexible und gut handhabbare Verteilungstyp der "zusammengesetzten Normalverteilung" genutzt wird. Da das Maximum zweier unabhängiger Zufallsgrößen näherungsweise als Summe ihrer Anteile dargestellt werden kann, lassen sich die Abhängigkeiten der Wege, die durch deren Überschneidungen entstehen, bei der Ermittlung von Projektzeitpunkten auf einfache Weise beachten. Vergleiche mit dem wesentlich aufwendigeren Simulationsverfahren weisen nur geringe Abweichungen der Ergebnisse aus. Die Zuverlässigkeit der gewonnen Aussagen hängt somit hauptsächlich von der Realitätsnähe der Zeitschätzungen für die einzelnen Vorgangsdauern ab. Das Verfahren ist auch auf Netzpläne mit verschiedenen Anordnungsbeziehungen und minimalen Zeitabständen anwendbar.

Friday, September 2, 10:30, Room MA043

On the Reducibility of Sequences

Heidemarie Bräsel, Otto-von-Guercke-Universität Magdeburg

We consider classical shop problems: n jobs have to be processed on m machines. The processing time t_{ij} of job i on machine j is given for all jobs and all machines. The machine orders are fixed (job shop) or arbitrary (open shop). We have to determine a feasible combination of machine and job orders (sequence) which minimizes the completion time of all jobs. The modelling of shop problems by means of special latin rectangles has led to some interesting ideas for solving certain open shop problems. A survey on these results will be presented in the talk. Now we define a partial order on the set of sequences. Independent of the given processing times for an ordered pair (A, B) the makespan of A is not greater than the makespan of B. Therefore, the optimal solution for such problems must be a minimal (or irreducible) element in the partial order defined above. We will discuss some properties of this partial order. The sets of minimal elements (irreducible sequences) can be described in detail for two machine shop problems. The cardinalities of these sets are calculated. For the open shop problem we construct classes of irreducible sequences. Furthermore, we describe an algorithm to decide wether a given sequence is irreducible. In the framework of processing times we develop a new world of sequences and schedules.

Friday, September 2, 11:00, Room MA043

Zur Anwendung der Head-Tail-Iteration bei Open-Shop-Problemen

Günter Deweß, Universität Leipzig

Im Open-Shop-Problem mit n Jobs und m Maschinen seien v_i die Operationen, d_i ihre Dauern, t_i ihre Anfangstermine im Ablaufplan. Zu minimieren ist der Endzeitpunkt $T(t_1, \ldots, t_{mn})$ der zuletzt endenden Operation, T' sei der durch den aktuell besten bekannten Ablauf gegebene Rekordwert.

Unser Verfahren für allgemeine Shop-Probleme ordnet jedem Knoten H des durch Entscheidungen entstehenden Verzweigungsbaumes Rahmen $[f_i^H, s_i^H]$ für alle v_i zu, falls $f_i^H \leq t_i \leq s_i^H - d_i$ für alle $T \leq T'$ erfüllenden Abläufe zu H gelten muß. Falls für diese Abläufe $t_i + d_i \leq t_j$ gelten muß, wird ferner $v_i <^H v_j$ in einer Halbordnungsrelation $<^H$ vorgemerkt. Bounds, Cuts (z. B. nach Carlier/Pinson) und die Auswahl der Verzweigungsentscheidung werden gefördert durch reichhaltigere $<^H$ und engere Rahmen bei zunehmender Höhe im Baum. Bei Nichtabbruch wird solange verzweigt, bis die f_i einen Ablauf t_i ergeben.

Bei Open-Shop-Problemen ist zunächst $<^0$ leer und $f_i^0 = 0$, $s_i^0 = T'$ für alle i, unsere Mittel haben und liefern also an den ersten Verzweigungsknoten des Baumes keine förderlichen Informationen. Deshalb erzeugen wir durch Vorentscheidungen Teilprobleme und wenden unser Verfahren auf diese an.

Das Gesamtverfahren löst 4x4- und 5x5-Probleme deutlich besser als bisherige, es löst erstmals effektiv 99% der 7x7- und 90% der 10x10-Probleme. Z. B. wurden 40000 zufällig erzeugte 5x5-Probleme in durchschnittlich 0.76 Sekunden pro Problem (22 Sekunden im ungünstigsten Beispiel) auf einem PC gelöst.

Friday, September 2, 11:00, Room MA309

On Scheduling Automated Laboratory Systems

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Automated Laboratory Systems with modular structure (blood-analysis oriented for instance) lead to challenging scheduling problems. Any analysis consists in a well defined sequence of basic steps (incubation, chemical reactions, ...) to be performed by specific modules of the ALS. Modules can work independently so that various analysis can be processed simultaneously.

The scheduling problem considered here is: Given a workload (i. e. how many samples to be tested and for which analysis) determine a feasible schedule of shortest possible length (i. e. exploit the modular structure for processing simultaneously various analysis).

The difficulty of the problem follows from the fact that:

- Waiting-times are not allowed between consecutive steps of an analysis.
- Actual duration of a step must be within a small percentage of a given ideal duration.

We propose a two phase heuristic approach for this problem, the second phase of which can be used for an on-line reactualization in case of small deviations appearing in the actual schedule (implementable on the relatively small PC's provided for controlling the process).

Friday, September 2, 11:30, Room MA309

Serial and Parallel Resource-Constrained Project Scheduling Methods Revisited: Algorithms, Theoretical and Experimetal Investigations

Rainer Kolisch, Christian-Albrechts-Universität zu Kiel

We consider the classical resource-constrained project scheduling problem (RCPSP) where j=1,...,J activities of a single project are scheduled subject to precedence and resource constraints such that the makespan of the project is minimised. Two of the oldest and most known heuristics for the RCPSP are the serial and the parallel scheduling scheme, respectively. Both can be applied as a deterministic single-pass or a probabilistic multi-pass (sampling) method. The majority of publications dealing with scheduling schemes for the RCPSP report only on the performance of one scheme when applied as a single-pass approach. The purpose of this paper is to provide an extensive comparison of the parallel and the serial scheduling scheme as follows: We give theoretical results on the ability of the scheduling schemes to derive feasible and optimal solutions. Further we report about an in-depth computational study which compares both scheduling schemes when applied as a deterministic single-pass and a probabilistic multi-pass (sampling) method. We provide results w.r.t. (i) the comparison of single-pass scheduling and biased random sampling, the performance of (ii) priority rules, (iii) the performance of scheduling schemes, and finally (iv) the impact of problem parameters.

Friday, September 2, 11:30, Room MA043

New Polynomially Solvable Cases of the Open Shop Problem.

Sergey Sevastjanov, Institute of Mathematics at Novosibirsk, Russia

We consider the open shop problem with n jobs and m machines. Denote M_i — the total length of operations of machine i, $M = \max_i M_i$, K — the maximum length of an operation, $T(S)$ — the length of a schedule S. Results of two types are obtained.

1. An approximation algorithm is presented wich constructs a schedule S with bound

$$T(S) \leq M + \left(\left\lceil \frac{(3m^2 - 2m)K}{M + 2mK} \right\rceil - 1 \right) K$$

in time $O(nm^2)$. In particular, we have

$$T(S) \leq M + (m-2)K \quad \text{if} \quad M \geq (m + 1 + \frac{1}{m-1})K;$$
$$T(S) \leq M + (m-1)K/3 \quad \text{if} \quad M \geq (7m-6)K.$$

2. We say that machine i^d is *dominant* if $M_{i^d} = M$ and $\Delta = M_{i^d} - \max_{i \neq i^d} M_i > 0$. The optimal schedule S_{opt} satisfies the equation $T(S_{\text{opt}}) = M$ and can be found in polynomial time in the following cases (running time is indicated in parentheses):

a) $m \geq 3,\ \Delta \geq (2m-4)K;$ $\quad (O(nm^2))$

b) $m \leq 4,\ \Delta \geq (m-1)K;$ $\quad (O(n))$

c) $M \geq (5.45m - 7)K,\ \Delta \geq (m-1)K.$ $\quad (O(n^2m^2))$

Friday, September 2, 12:00, Room MA309

A Pseudo-polynomial Algorithm for the Completion Time Variance Problem with Controllable Processing Times

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We investigate the problem of scheduling n independent jobs on a single machine. The processing times p_i $(i = 1, \cdots, n)$ of the n jobs are decision variables whose values can be compressed between $[l_i, u_i]$. Past research mainly concerned with minimizing the sum of a first order function and a cost function of compression. In this paper, we consider a new model with the aim to minimize the sum of CTV (Completion Time Variance) and a linear cost for compression. Mathematically, it is to choose a schedule of the n jobs and n processing times to minimize

$$\sum_{i=1}^{n} (C_i - \overline{C})^2 + \sum_{i=1}^{n} b_i (u_i - p_i),$$

subject to $l_i \leq p_i \leq u_i$, where C_i is the completion time of job i, $\overline{C}$ is the mean completion time and $b_i > 0$ is the unit compression cost of job i. The CTV problem, which is NP-hard, can be considered as a special case of our problem when $l_i = u_i$ for all i. Up to now, there is no algorithm, except complete enumeration of all the schedules of the n processing times, to solve this problem. We show, in this paper, that if an agreeable condition (i.e. $l_1 \leq l_2 \leq \cdots \leq l_n$, $u_1 \leq u_2 \leq \cdots \leq u_n$ and $b_1 \leq b_2 \leq \cdots \leq b_n$) is satisfied, then our problem can be solved by a pseudo-polynomial algorithm with time complexity bounded above by $O(n^2 u_n U^2)$, where $U = \sum_{i=1}^{n} u_i$.

Friday, September 2, 12:00, Room MA043

Nonstrict Vector Summation in Job Shop Scheduling

Sergey Sevastjanov, Institute of Mathematics at Novosibirsk, Russia

1. We say that a permutation $\pi = (\pi_1, \ldots, \pi_n)$ of numbers $\{1, 2, \ldots, n\}$ specifies a *nonstrict summation* of vectors $X = \{x_1, \ldots, x_n\}$ in $C \subset R^m$ if for any $k = 1, \ldots, n-1$ the relation $\sum_{j=1}^{k} x_{\pi_j} \notin C$ implies $\sum_{j=1}^{k+1} x_{\pi_j} \in C$.

2. Let $C \subset R^2$ be an unlimited convex set such that $0 \in C$ and norm s of each diameter of C is at least 1. Then for any s-family of vectors $X \subset R^2$ a permutation $\pi = (\pi_1, \ldots, \pi_n)$ can be found in $O(n \log n)$ steps that specifies nonstrict summation of X in C. If C has a diameter arbitrarily close to but shorter than 1 then verification of nonstrict summability for a given instance of s-family is strongly NP-hard.

3. Three scheduling problems are considered: flow shops (FS); two-stage assembly line (AL); "crossing routes" $(1, 2, 3)$ and $(2, 1, 3)$ of jobs on three machines (CrR). Each problem $X \in \{FS, AL, CrR\}$ is reduced to a corresponding nonstrict vector summation problem ($NVSi,\ i = 1, 2, 3$) in a family of semispaces. Using the result of p.2, we get approximation algorithms for the $NVSi$-problems in R^2. This firstly implies that for any instance of the FS-, AL- or CrR-problem with three machines its optimum belongs to the interval $I_{FS} = [M, M + 3K]$, $I_{AL} = [M, M + 1.25K]$, $I_{CrR} = [M, M + 4K]$, correspondingly (the first two intervals being tight; M is the maximum machine load, K is the maximum operation length) and secondly yields an $O(n \log n)$ algorithm for each problem X with schedule length in the interval I_X.

Friday, September 2, 15:30, Room MA043

Timetabling Under Partially Renewable Resource Constraints

Andreas Drexl, Universität Kiel
Frank Salewski, Universität Kiel

A recurring problem in timetabling involves the allocation of scarce resources (teachers, rooms etc.) to lectures. In scheduling theory renewable and nonre- newable resources are usually distinguished. The usage of renewable resources is limited for every period and nonrenewable resources are restricted to an overall consumption within the whole planning horizon. While these resource types only allow to formulate capacity constraints for exclusively one or all of the periods, in timetabling capacity constraints formulated for subsets of periods are necessary (e.g. at most a two-hour lecture in mathematics on monday morning). Partially renewable resources are obtained by assuming for each resource a capacity on subsets of periods. Obviously, renewable resources and nonrenewable resources are special cases of this more general concept. While renewable resources are defined on subsets consisting of exactly one period, nonrenewable resources are restricted to the set of all periods of the planning horizon. In this paper we formulate an advanced timetabling model, which makes use of partially renewable resources. For the solution of the model we present semi-greedy and genetic algorithms.

Friday, September 2, 16:00, Room MA043

Timetabling by Genetic Algorithms

Werner Junginger, Universität der Bundeswehr Hamburg

Genetic algorithms are being applied in the last years to different problems with increasing success. In this paper its application to the timetabling problem will be investigated. As there are different instances of the timetabling problem, the following problem will be regarded:

Given c courses with different time-lengths and s students, each of them having chosen some courses. Find as a timetable a distribution of all courses to z periods such that no student has to participate in two courses at the same time.

To solve this problem by genetic algorithms, first its representation as a bit-string is presented. Then possibilities of crossover and mutation are discussed. This results in an algorithm for solving the timetable problem given above. Experiments on applying this algorithm to examples will be reported finally, and also proposals for further investigations.

Friday, September 2, 16:30, Room MA043

The Use of Simulation for Time Scheduling and Production Optimization in the Graphic Arts Industry

Frank Schumann, Hochschule für Technik, Wirtschaft und Kultur Leipzig (FH)

The subject of the contribution is to give evidence for the usability of simulation programms for the realisation of the time planning exemplary demonstrated on a simulation based ppc-system for the graphic arts industry. Within an input-block the specified orders are assigned to standardsized technological sequences (sequences of machines). Corresponding to these technological sequences and to the sequence of jobs in the jobpackage, simulation is carried out to determine the handling dates and the preparation and handling times. An optimizing module improves the first results of the simulation step by step based on the evaluation fo the through-put-times, intensity of use of the machinery, the share of preparation times, etc. These module includes concepts for the common procedures of sequence optimizing and of ensuring a consistent use of the main machines. The main item, the simulation programm, is integrated in the common database based periphery of special software common in the graphic arts industry, such as that for calculation, controling, electronic planning table, etc. Amongst visualisation of the process and a stronger orientation on the certain company the essential advantages of the central simulation use are the more accurat estimating, the better allocation of resources and the possibility of optimizing the jobpackage.

Friday, September 2, 17:00, Room MA043

Scheduling Problems with Multi-Processor-Tasks on Dedicated Processors

Peter Brucker, Universität Osnabrück
Andreas Krämer, Universität Osnabrück

(Shop) Scheduling problems with multi-processor-tasks on dedicated processors are investigated. Such tasks may require several pre-specified processors at the same time.

First we give a survey on recent complexity results derived for multi-processor-task (shop) scheduling problems.

Next we present branch and bound approaches for these problems based on a formulation of the scheduling problem by a disjunctive graph G. The basic difference of these approaches is the representation of the feasible schedules.

The first is based on the representation of schedules by selecting disjunctive arcs. Therefore branching is done by turning arcs into opposite directions. It is a straightforward generalization of the branch and bound procedure for the classical job shop problem by Brucker et al. In the second approach schedules are calculated by determing the (minimal) extensions of G which are partially ordered comparability graphs. The branching rule defines if an edge should be added or not to the set of disjunctions. It is a generalization of the branch and bound procedure by Bianco et al. for the version of the problem without precedences. The last approach is close to the second. Again the branching rule defines if an edge should be added or not to the set of disjunctions. If an edge between nodes i and j of G is not added to the set of disjunctions the corresponding operations are assumed to be scheduled in parallel for some time.