Math. Forschungsinstitut Oberwolfach
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MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

# Tagungsbericht 10/1984

## Operations Research

26.2. bis 3.3.1984

Diese Konferenz über Operations Research fand unter Leitung von Herrn K. Neumann (Karlsruhe) und Herrn D. Pallaschke (Karlsruhe) statt.
43 Teilnehmer aus 7 Ländern waren eingeladen, ihre neuesten Resultate aus ihrem Forschungsbereich zur Diskussion zu stellen.
Es kam, wie immer bei solcher Art von Klausurtagungen, zu einem regen Informationsaustausch in Form von Vorträgen und zusätzlichen Diskussionen.
Auf diese Weise wurde das Ziel der Organisatoren der Tagung vollumfänglich erreicht, nämlich :
die Förderung des Erfahrungsauschtausches innerhalb und zwischen den verschiedenen Gebieten des Operations Research und die Diskussion über neuere Entwicklungsrichtungen in diesem Zweig der Wissenschaft.
Diese Konferenz hat sich als eine wirksame Plattform für den Austausch neuer Ideen erwiesen und das gegenseitige Verständnis für die verschiedenen Forschungsschwerpunkte gestärkt.
Themen aus verschiedenen Bereichen des Operations Research wurden diskutiert. Die in den Vorträgen vertretenen Gebiete waren:

- Mathematical Programming
- Game theory
- Graph Theory
- Queueing Theory
- Network Theory
- Control Theory
- Special Stochastic Problems in OR
- Applications of OR in Economy

Schon von Beginn der Konferenz an ließen die Vorträge und Diskussionsbeiträge, aber auch die persönlichen Fachgespräche unter den Teilnehmern, einen langfristigen stimmulierenden Effekt auf die zukünftige Forschung in den o.a. Gebieten erwarten.
Die herzliche Atmosphäre und die vorzügliche Einrichtung des Mathematischen Forschungsinstituts sorgten zusätzlich für den harmonischen Rahmen, in welchem diese Tagung stattfand, und die von allen Teilnehmern hochgeschätzt und dankbar anerkannt wurden. Im besonderen sei hier der Dank an den Direktor des Instituts, Prof. Dr. Barner, erwähnt.

Um die Ergebnisse dieser Konferenz auch einem größeren Publikum zugänglich zu machen, erscheint im Sommer 1984 ein Proceedings-Band dieser Tagung beim Springer Verlag, Heidelberg.

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## Vortragsauszüge

A. BACHEM:

### Theory of Polyhedra in Oriented Matroids

Polar lattices, i.e. lattices antiisomorphic to a given lattice L have wide applications in polyhedral theory, especially in the blocking and antiblocking theory. Recently polyhedral face lattices are generalized to tape lattices of oriented matroids. Unfortunately in general these tape lattices fail to have a polar lattice. The reason is that geometric lattices do not always have an adjoint. In this talk we report on joint results with W. Kern, where we show, that an oriented matroid $\bar{O}$ is an adjoint of an oriented matroid O if and only if $\bar{O}$ can be embedded into the extension lattice of O. This theorem also proves that oriented matroids do have polars if they do have adjoints. Finally we use these results to give a new characterization of linear matroids.

R. BURKARD:

### Eigenfunctions and Optimal Orbits

Given $a_{ij} \in \mathbb{R}$ the problem $\max_j (a_{ij}+x_j) = \lambda + x_j$ $(i=1,2,..,n)$ is known as eigenvalue problem in the max-algebra ( $\mathbb{R}$,max,+). This problem plays a role in OR-Problems related to shortest paths, e.g. in industrial scheduling. For solution methods see R.A. Cuninghame-Green ("Minimax-Algebra",Springer LN Econ.vol.166) and U. Zimmermann ("Linear and Combinatorial Optimization in Ordered Algebraic Structures", Ann. Disc. Maths. vol.1o).
In the following the continuous counterpart of this problem will be discussed. Given $A: \mathbb{R}^n \times \mathbb{R}^n \to \mathbb{R}$ , find an " eigenfunction" $f(x)$ and an "eigenvalue" $\lambda$ s.t. $\max_y (A(x,y)+f(y)) = \lambda + f(x)$ for all $x \in \mathbb{R}^n$.
As in the discrete case this problem is related to " optimal orbits" which generalize shortest paths.
For each $x \in \mathbb{R}^n$ let $\theta(x)$ be the unique solution of $\max_y (A(x,y) + f(y))$. A sufficient condition for the existence of $\theta$ is given by the following theorem.

Let $\Gamma(u,v,w) = \begin{pmatrix} \Gamma_{11} & \Gamma_{12} \\ \Gamma_{21} & \Gamma_{22} \end{pmatrix}$ be the functional matrix

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defined by $\gamma_{ij} := \begin{cases} \partial_i \partial_j A(u,v) & , \quad i=1,2,..,n \quad j=1,...2n \\ \partial_i \partial_j A(w,u) & , \quad i=n+1,....2n \quad j=1,...2n \end{cases}$

where $_i$ denotes the partial drivative with respect to the i-th argument. Now we get:

<u>Theorem 1</u> If $(\Gamma_{11}+\Gamma_{22})$ is nonsingular for all $u,v,w \in \mathbb{R}^n$ and $\max\left( \| (\Gamma_{11}+\Gamma_{22})^{-1} \Gamma_{12} \| , \| (\Gamma_{11}+\Gamma_{22})^{-1} \Gamma_{21} \| \right) < \frac{1}{2}$

then there is a unique function $\theta(x)$ ,

$\theta(x) = \max_y (A(x,y)+f(y))$, which is a contraction.

Moreover we get, if $\Theta(x)$ denotes the derivative of $\theta(x)$ :

<u>Theorem2</u> If $\Gamma_{22}(x,y)+\Gamma_{11}(y,\theta(Y))+\Gamma_{12}(y,\theta(y))\cdot\Theta(y)$ is a symmetric negative-definite matrix for all $x$ and $y \in \mathbb{R}^n$, then there is an eigenfunction $f$ and an eigenvalue $\lambda$ with:
$\max_y (A(x,y)+f(y)) = \lambda + f(x)$ for all $x \in \mathbb{R}^n$.
In particular $\lambda = A(\xi,\xi) = \max_z A(z,z)$; where $\xi$ is the fixed point of $\theta$ .

In the case of a concave quadratic function A ,explicit formulas for $\theta$ , $f$ and $\lambda$ can be given.Also the separable case $A(x,y)= R(x)+S(y)$ can explicitly be solved.
Finally it is shown that the corresponding optimal orbit problem has a finit solution iff $\lambda = 0$. The optimal objective function value is given by $f(x) - f(\xi)$ .

Reference:
R.A. Cuninghame-Green and R.E. Burkard: Eigenfunctions and Optimal Orbits, Bericht 83-3o,Institut f. Mathematik , TU and Univ. Graz, Nov 1983.

V.F.DEMYANOV:

<u>Numerical Methods in Non-smooth Optimization</u>

A new class of nondifferentiable functions - so called quasidifferentiable functions - is discussed. Since any positively homogeneous smooth function can be approximated as a difference of two positively homogeneous convex functions, then directional derivative of any Lipschitzian directionally differentiable functions can be approximated by a quasidifferentiable function. But for a quasidifferentiable function it is known how to compute its steepest descent ( and if necessary steepest ascent ) directions.

For minimizing a smooth composition of maximum functions

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a numerical method is described. The main feature of the method is the fact that at each step it is necessary to solve several one-dimensional optimization problems ( not necessarily exactly).

W. EICHHORN:

The Optimal Value of the Investment Ratio of an Economy

The investment ratio in the year t

$$u_t = \frac{I_t}{Y_t} = \frac{\text{Gross domestic investment during the year t}}{\text{Gross domestic product during the year t}}$$

of Japan, D,F,GB,I,USA have got quite different values in the last years. These values are ranging from o.16 to o.36. In order to find the "optimal values" $u_t^*$ the following problem is solved with the aid of methods of discrete dynamic programming:

$$\text{maxConsumption} = \max \sum_{t=1}^{T} r^{(t-1)}(1-u_t)Y_t\ ,$$

($r_t \in (0,1)$ "discount factor"), where

$$r^{(t-1)} := r_2 r_3 \cdots r_t,\ r^{(o)} := 1,\ Y_t = F(K_{t-1})$$

$K_{t-1}$= capital stock at the beginning of the year t,
$K_o$ given, $T \geq 3$, $F_t\colon \mathbb{R}_+ \to \mathbb{R}_+$ the ( strictly concave and twice differentiable) production function of the economy subject to

$K_t = u_t F_t(K_{t-1}) + q_t K_{t-1}$ ($q_t \in (o,1)$,"depreciation factor").

It turns out, that $u_t^*$ (t=1,2,...T) depends on $q_t, q_{t+1}, r_t, r_{t+1}$, and the shape of $F_t$ and $F_{t+1}$, but not on the q's,r's and F's with higher indices. The reason for this is shown. If $r_t=r$ , $q_t=q$, $F_t=F$ for all t and if $F(K) = c \cdot K^\gamma$ ( c and $\gamma<1$ positive reals ) then :

$$u_1^* \neq u_2^* = u_3^* = \cdots = u_{T-1}^* = \frac{1-q}{1-rq} \cdot r\gamma$$ . Note that this is

o.229, i.e. the 198o investment ratio of D, if q=o.9, r=o.97, $\gamma$=o.3 ( which are quite realistic values).

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G. FEICHTINGER:

Maximumprinzip und Firmendynamik

Die kontrolltheoretische Analyse dynamischer Unternehmensmodelle (" Dynamics of the firm" ) wird anhand dreier Modelle illustriert. Für eine monopolistische, profitmaximierende Firma werden zunächst simultane Preis- und Produktionspfade ermittelt; als Zustandsvariable dient der ( nicht-negative) Lagerstock. Führt man den Produktionsfaktor Arbeit mit konvexen Hiring/Firing - Kosten ein und läßt kein Lager zu ( konvexe Fehlmengen- und Vernichtungskosten), so erhält man ein Model zur Bestimmung optimaler Einstellungs-,Entlassungs- und Lohnpolitiken einer Firma. Durch Kombination der beiden ersten Modelle ergibt sich ein nichtlineares Kontrollproblem mit zwei Zuständen (Lager- und Beschäftigungsstand) und reinen Zustandsnebenbedingungen ( Nichtnegativität von Lager- und Arbeitskräfestock), für welches es die optimalen Lagerhaltungs- und Beschäftigungsstrategien zu bestimmen gilt.

W. GAUL:

Multistate Reliability Problems for GSP-Digraphs

Assume that the arcs of the underlying graph can take m+1 states of reliability from complete failure (state 0) to perfect functioning ( state m) $m \in \mathbb{N}$ .
For m=1 an extensive literature about reliability problems on graphs is available, for m > 1 this talk gives bounding distribution functions for the distribution function of a reliability measure of the graph in terms of properly choosen subgraphs.
A successive determination of the bounding distribution functions ( and of bound for the expection, variance , etc. if necessary ) of the reliability measure is possible allowing improvements on to the choice of proper subgraph systems.

M. GRÖTSCHEL:

Triangulation of Input-Output- Matrices

We report about the successful attempt to triangulate large input-output- matrices. To solve problems of this

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type we have developed an LP-based cutting plane algorithm (with a final branch&bound phase) with which we could triangulate all real world input-output-matrices known to us ( which are of size at most 6o X 6o).
The algorithm is based on results of polyhedral combinatorics. The feasible solutions of the triangulation problem can be considered as spanning acyclic tournaments in a complete digraph, and in turn, the convex hull of the incidence vectors of these tournaments is a polytop P whose vertices are in 1-1 correspondence with the triangulations. We were able to describe large classes of facets of P and could use the corresponding inequalities efficiently as cutting planes in our algorithm.

G. HAMMER:

Kurzsichtige Heuristiken für das Mengenüberdeckungsproblem

Für zwei kurzsichtige ( greedy- ) Heuristiken zur Lösung des Mengenüberdeckungsproblems

$$\min \{\Sigma v_i x_i : Ax \geq p,\ x \in \{0,1\}^I \},\ p \in N^U,\ A_u^i \in \{0,1\},\ v_i \in \mathbb{R}$$

werden (scharfe ) Garantien abgeleitet, von denen eine ein Resultat verallgemeinert, das Chvatal (1979) für p = 1 fand. Rechentests mit zufällig erzeugten Daten zeigen aber, daß die Garantien allein keine verläßlichen Rückschlü auf das durchschnittliche Verhalten der Algorithmen zulassen.

E. HÖPFINGER:

Bounding Distributions for an Acyclic GERT-Network

The exact time-analysis of GERT-networks usually is a cumbersome effort. A way to ameliorate this is the calculation of bounding distributions for the distribution function of the network-termination. In the case of acyclic GERT-networks without stochastic nodes a theorem on associated random variables can be exploited for the calculation of bounding distributions. Applied to PERT-networks these coincide with the ones developed by Shogan.
The bounds do not allow inequalities for the integration of a monotone increasing multivariate function. Since the random variables of a GERT-network with stochastic nodes

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the procedure can only be used after the realization of the stochastic nodes.

A.HORDIJK §:

Selection of Order of Observation in Optimal Stopping Problems

In optimal stopping problems in which the player is free to choose the order of observation of the random variables as well as the stopping rule, it is shown that in general there is no function of all the moments of individual integrable random variables, nor any function of the first n moments of uniformly bounded random variables, which can determine the optimal ordering. On the other hand, several fairly general rules for identification of the optimal ordering based on individual distributions are given, and applications are made to several special classes of distributions.

§ This research is joint work with Th.P. Hill

D. KADELKA:

On an Optimal Harvesting (Replacement) Problem

We investigate a stochastic model of optimal harvesting, first introduced by R.S.Kaplan (1972). At each time point n the value of some biological asset is known to the decision maker. He has to decide whether to let the asset mature one more time period or to harvest it completely and to plant another asset of the same kind. The growth of the asset is governed by an arbitrary stochastic law, dependent on the current value. The problem is to maximize the expected discounted value of the cash flow stream generated by the growth and harvesting process for finite or infinite horizon. In this talk we present conditions implying the existence of an optimal policy of the control-limit type. The formulation of the model will be of sufficient generality to include some models of optimal replacement.

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P.S.KENDEROV:

## Most of the Optimization Problems are Well-Posed

Let X be a compact metric space, C(X) be the space of all continuous functions on X with the usual max-norm. The space $2^X$ of all closed subsets of X will be equipped with the Hausdorff metric. Each of the optimization problems of the type min f(x) x ∈ A , where $A \in 2^X$ and $f \in C(X)$, can be considered as an element of the set $2^X \times C(X)$. It turns out that, outside some first Baire category subset of $2^X \times C(X)$, all elements of $2^X \times C(X)$ generate an optimization problem which has unique solution and this solution depends continously on the pair $(A,f) \in 2^X \times C(X)$.
This result remains valid for much more general (than compact metric ) spaces X.
Let X and Y be Eberlein compacta. The set of functions $K(x,y) \in C(X \times Y)$ which generate antagonistic games with only one solution (i.e. only one saddle point ) is dense and G-subset of $C(X \times Y)$.

E. KÖHLER:

## " 18 "

Definition: Ist $V \in$ Me mit $|V| = v \in \mathbb{N}$, $v/2 \geq k \in \mathbb{N}$, $\mathcal{B} \subset \binom{V}{k}$, $k > t \in \mathbb{N}$, $\lambda \in \mathbb{N}$, $T \in \binom{V}{t}$ und

$$\mathcal{B}_T := \{B \cap T \mid B \in \mathcal{B} , T \subset B \}$$, so heißt $\mathcal{B}$ ein

$$S_\lambda(t,k,v) :\Leftrightarrow \mathcal{B}_T = \quad \text{for all } T \in \binom{V}{t}.$$

Satz: Ein $S_\lambda(4,5,18)$ existiert $\Leftrightarrow \lambda \in \{2,4,6,8,1o,12,14\}$.
Bew.: Mit Hilfe der affinen Gruppe $\mathfrak{A}_{17} \times \{\infty\}$ .

B. KORTE:

## Combinatorial Structures, Convexity and Topological Relations

One of the very many ways of defining matroids on a ground set E is via a closure operator $\sigma: 2^E \to 2^E$ which is monoton and idempotent and which satisfies the (symmetric) Steinitz-McLane exchange property (SM): $y,z \notin \sigma(X)$, $y \in \sigma(X \cup z)$ implies $z \in \sigma(X \cup y)$. (The linear hull operator in vector

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spaces has this property). An antisymmetric version of (SM) leads to (ASM): $y,z \notin \sigma(X)$ and $y \in \sigma(X \cup z)$ implies $z \notin \sigma(X \cup y)$. (The convex hull operator in linear spaces shares this property). Combinatorial structures with a monotone and idempotent closure operator which enjoys (ASM) are called antimatroids or shelling structures ( special cases of greedoids). We study properties of these structures especially some axiomatic based on circuits. The Happy End Theorem of Erdös and Szkeres can be extended to these structures. Furthermore, we introduce suitable connectivity definitions for greedoids. We can prove with homotopy methods some equivalences between connectivity of greedoids and (topological) connectivity of related simplicial complexes and polytops. This is part of a joint work with Laszlo Lovasz, Budapest.

P. KOSMOL:

## Selection of Solutions By Algorithms

Suppose you have chosen a method for the solution of a problem which may have more than one solution, then you have made automatically a selection amongst possible solutions. If we replace a problem by a sequence of approximating problems,whose solutions can be interpreted as solutions of variational inequalities ( optimization problems, equations, saddle- and equilibrium point problems), then the solutions we obtain, are the solutions of a two stage variational inequality. The inherent difficulty consists in finding the appropriate variational inequality. The numerical behaviour of the method depends on this "second stage inequality".
There are even problems whose "solutions" cannot be interpreted but as the limit of the sequence of solutions for approximating problems. An interesting example is the well-known problem from optics ( cf. books for calculus of variations):

$$\text{minimize } f(y) := \int_0^a \frac{\sqrt{1+\dot{y}^2(t)}}{y(t)}\,dt \qquad \text{subject to}$$

$y \in C^1(0,a]$ , $y(0) = 0, y(a) = b$, $y \geq 0$.
It is obvious that this problem cannot have a minimal solution in the usual sense, since the function f becomes for all feasible points, because:

$$\int_0^a \frac{\sqrt{1+\dot{y}^2}}{y} \geq \int_0^a \frac{\dot{y}}{y} = \ln y \Big|_{0+}^{a} = \infty$$

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R.H. MÖHRING

Recent developments in Stochastic Scheduling Problems II

The talk introduces the finite class of set strategies for stochastic scheduling problems. It is shown that the known stable classes of strategies such as ES and MES strategies are of this type, as are static priority strategies such as LEPT and SEPT and other, more complicated priority strategies. Roughly speaking, set strategies are characterized by the fact that the decision as to which jobs should be started at time t depends only on the knowledge of the two sets of jobs finished up to time t and being processed at time t. It is demonstrated that the set strategies have usefull properties. They are e.g. $\lambda^n$-almost everywhere continuous and therefore show satisfactory stability behaviour w.r.t. weak convergence of the joint of job durations. Furthermore, the optimum w.r.t. all strategies is already attained on this class if job durations are independent and exponentially distributed and the performance measure fulfills a certain shift condition. This shift property strengthens aspects of the notion of additivity in semi-Markov decision theory. Typical additive cost criteria such as makespan and flowtime are therefore covered, yielding simultaneously a first step towards generalization of optimality of LEPT and SEPT rules, as known for special classes.

M. MORLOCK:

Aspects of Optimization in Automobile Insurance

In most of the countries experience rating is used in automobile insurance. On the basis of a simple model the resulting credibility premiums - optimal in the sense of Bayesian estimators - are compared with the bonus-malus classes of motor insurance in the FRG of today. The critical point in this approach is the knowledge of the structure function; this is exemplified by the german automobile insurance and its actual problems. Results without using a structure function are presented. To derive an optimal Bonus-System within the framework of the model an heuristic procedure is presented. The last aspect of optimization deals with optimal bounds for the " bonus-hunger" which can be computed by means of dynamic-programming. For the special case of an exponential distribution for the amount of claims, it is shown that the solution of this optimization is given by the solution of some Bernoulli differential equations.

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K. NEUMANN:

GERT Networks with Tree Structure: Properties, Temporal Analysis, Cost Minimization and Scheduling

GERT networks all of whose nodes have OR entrance and deterministic or stochastic exit and which are also called OR networks are considered. The assumption that, figuratively speaking, different walks emanating from a deterministic node do not meet anywhere in the OR network in question results in a certain tree structure: if we shrink all components of the OR network to one node each, then any partial network whose activities are carried out during a single project execution represents an outtree. Using the above assumption it can also be shown that each OR network can be covered by d+1 STEOR network ( GERT networks all of whose nodes have exclusive-or entrance and stochastic exit), where d is the so-called deterministic degree of the OR network.
Each STEOR network is associated with a Markov renewal process whose renewal functions yield the "temporal analysis" of the STEOR network. The determination of the optimal time-costs trade-offs for STEOR networks leads to a stochastic dynamic programming problem or an optimal control problem. Due to the above "covering property" , temporal analysis and cost minimization of OR networks can be reduced to the same problems for STEOR networks.

If one resource of capcity 1 is required to execute each activity of a project described by an OR network, we obtain a stochastic single-machine scheduling problem with precedence constraints given by the OR network. This scheduling problem with expected weighted sum of the completion times of all activity executions as objective function can be solved by a generalization of Smith's ratio rule in polynomial time.

J. van NUNEN:

On Using the Linear Programming Relaxation of Assignment Type Mixed Integer Programming

We prove in this talk that tight upper bounds can be given for the number of non-unique assignments that remain after solving the linear programming relaxation of some types of assignment problems. These bounds are given explicitly for mixed integer problems of which the pure integer constraints are of the multiple choice type or of the assignment type. Heuristics are described to assign the remaining fractional assignments. Practical applications like a brewery distribution problem and time table problems are discussed.

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D. PALLASCHKE:

## Formulas for Numerical Differentiation With Minimal Norm

The following results are based on a theorem of Rolewicz, which states the following:

> Let E,F be finit dimensional Banach-spaces, $\Omega$ a compact topological space and A: E $\to$ $C_o(\Omega)$ , B: E $\to$ F continuous linear operators.
> If there exits a $\Phi : C_o(\Omega) \to F$ such that $\Phi \circ A = B$, then there exists a $\Phi_o : C_o(\Omega) \to F$ with minimal norm,
>
> such that $\Phi_o(x) = \sum_{i=1}^{m \cdot n} x(t_i)\alpha_i$, with $\alpha_i \in F$,
>
> $t_i \in \Omega$ , $n = \dim E$ , $m = \dim F$ .

This theorem is used for numerical differentiation:

> If $\Omega := [-1,1]$ the points $t_i$ are the extremals of the n-th Čebeysev polynomial $T_n$ and
>
> $\Phi_o(x) = (L_n(x))^{(k)}$, where $L_n$ is the Lagrange
>
> Interpolation in this nodes.

Convergence theorems for derivates are proved.

F.J. RADERMACHER:

## Recent Developments in Stochastic Scheduling Problems I

The talk gives an overview over some recent developments in the field of nonpreemptive stochastic scheduling problems. Covered are arbitrary joint distributions of activity durations, arbitrary regular measures of performance and arbitrary precedence and resource constraints. The class of all strategies is characterized via a functional as well as a stochastic optimization approach and results on the existence of optimal strategies are presented. In addition, the possible instability of the problem is demonstrated and hints are given on stable subclasses of strategies available, including the combinatorial vs. analytical characterization of such classes. The main emphasis of the talk finally is on monotonicity results. Using quite involved insights into certain stochastic processes associated with stochastically comparable distributions, the monotone behaviour of the optimal value is shown under quite general assumptions, covering the case of stochastically independent distributions of job durations.

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P. RECHT:

On an Algorithm for Solving Convex, Quadratical Programming Problems

Based on the update formulas of Pallaschke-König an Ellipsoid-Algorithm for convex, quadratical programming problems is given.
This algorithm allways uses the objective function f for starting ellipsoidal iterations.
It is proved that this algorithm constructs a sequence of boundary points $x_k^*$ of the set S of feasible solutions. ( S closed, convex, $int(S) \neq \emptyset$ ).
The sequence $(x_k)$ is linearily convergent to the optimal vector x with strictly decreasing objective function values $f(x_k)$.
An example is given for the case that S is a polyhedron, and some conjectures about the structure of the algorithm are made.

S. ROLEWICZ §:

On Stability of Linear Time-Varying Infinite Dimensional Discrete-Time Systems

The asymptotic behaviour of linear time-varying infinite dimensional discrete-time systems is considered. The introduced notations are: " weak power equistability ", "power equistablity ", " uniform power equistability " " $l^p$-equistability", "uniform $l^p$-equistability " and " $l^{p(x)}$ - equistability". It is shown,that they are identical. A generalization of the concept of spectral radius of a single operator on a sequence of operators is proposed. It is proven that any time-varying system is uniformly power equistable if and only if the generalized spectral radius of the sequence of operators describing the system is less than one.

§ This research is joint work with K.M. Przyluski .

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J. ROSENMÜLLER:

## Representation of Homogeneous Games

A natural vector $(g,k) \in \mathbb{N}^{2r}$ $g_1 < g_2 < \dots < g_r$ constitutes a finite "measure" M on a set $\Omega = K_1 + \dots + K_r$ , $|K_\rho| = k_\rho$ ( $\rho = 1,2,\dots,r$) via

$$M(S) = \sum_{\rho=1}^{r} |S \cap K_\rho| \, g_\rho \quad (S \subset \Omega)$$

and a "game" $v = v_\lambda^M : \mathcal{P}(\Omega) \to \{0,1\}$ by $v(S) = 1_{[\lambda, M(\Omega)]} \circ M(S)$

where $\lambda \in \mathbb{N}$ is the " majority level".
A game v is homogeneous if there exists M and $\lambda$ s.t. every minimal winning coalition has weight $\lambda$ . In this case we say that " M hom $\lambda$ ".
A basic lemma states, that M hom $\lambda$ iff there is $i_o \in \{1,2,..r\}$ and $c \in \mathbb{N}$, $1 \le c \le k_{i_o}$ such that

$$\lambda = c \cdot g_{i_o} + \sum_{i=i_o+1}^{r} k_i \cdot g_i \qquad \text{and } M_{i_o}^c \text{ hom } g_i \quad (i \ge i_o)$$

where $M_{i_o}^c$ is the " rest measure" when mass $\lambda$ is removed from

$\Omega$ . Thus $\lambda$ is reached by the "lexicographically largest" coalition and smaller players play homogeneous games in order to replace larger ones in this coalition.
Ostmann (1983) proved that min{ $M(\Omega)$ | there is $\lambda$ $v = v_\lambda^M$ } is uniquely solved. This hom games have a unique representation which is homogeneous. ( no zero-sum property!)
Using the basic lemma one may specify:

1. a recursive procedure to generate all homogeneous games
2. a procedure obtain the minimal representation of a game from those of the subgames.

R. SCHASSBERGER:

## Zur Bestimmung der stationären Zustandswahrscheinlichkeiten bei Wartesystemen

Es wird an Beispielen aus der Theorie der Warteschlangen gezeigt, daß es zur Bestimmung der stationären Verteilung einer Markovkette vorteilhaft sein kann, diese zunächst nur auf einem Teil des Zustandsraumes, etwa einem "Rand" zu beobachten.

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M. SCHÄL:

Optimal Stopping of a Markov Chain as Average Return Problem

It is well known that there exists an a.s.finite optimal stopping time for the problem of stopping a Markov chain with finite state space. This result is extended to the situation where one can control the markov chain also before stopping. In the theory of gambling the theorem states:
in a leavable gambling house with finite fortune space and additional compactness and continuity properties there exists an optimal strategy which a.s. staguates.
The theorem is proved by dynamic programming methods for the average return. This is possible because of the fact that the difference between the gambling criterion limsup $u(i_n)$ and the average return criterion

$$\lim \frac{1}{n}( u(i_o)+....+u(i_n) )$$

disappears for trajectories $(i_o,i_1,...)$ which eventually staguates.

H. SCHELLHAAS:

Computation of the Stationary State Probabilities in Semi-Regenerative Queuing Models

We consider a unifying queueing model covering several well known models such as M/G/1-queues, M/G/1 - queues under a k-policy, M/G/1 - queues under a T-policy, M/G/1 - queues with repeated attempts, repairman problems. Input and service may be state dependent, so that models with finite and infinite waiting rooms may be treated simultaneously.
The arrival process during the service of a customer is a pure birth process with state dependent birth rates.
As soon as a customer is served, the server takes a vacation of stochastic length ( state dependent) . Thereafter a service follows etc., vacations of length zero ( with probability 1) are permited.
Let $Z(t)$ be the number of customers in waiting room at time t and $L(t)=1$ ( $=0$) if the server is busy (in vacation) at time t. We assume that $\{(Z(t),L(t)), t \in \mathbb{R}_+\}$ is a semi-regenerative process. We construct a numerically stable algorithm to compute the steady state probabilities for the process $\{(Z(t),L(t)), t \in \mathbb{R}_+\}$ using a general limit theorem for semi-regenerative processes.
The state probabilities are computed recursively, for the

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coefficients in the recursive scheme an explicit integral representation is given. The calculation simplifies considerably if the service time distributions are of phase type. Then the representation of the coefficients reduces to simple matrix-vector operations.

N.SCHMITZ:

An Improved Bound for $S_n/n$

A prominent problem in the theory of optimal stopping is the $S_n/n$ problem.

Let $X_1, X_2 \ldots$ be a sequence of i.i.d. random variables

with $P(X_1=1) = P(X_1=-1) = 1/2$

and let $S_n = X_1+X_2+\ldots+X_n$.

One can decide to stop at any time point n receiving the reward $S_n/n$. The goal is to maximize the expected reward. Though famous mathematcians have attached it,it is not yet completely solved, e.g. the best known bounds for the optimal value $v^*$ (due to Bellman/Dreyfus and Chow/Robbins) seems to be

$$0.5850 \leq v^* \leq 0.98 \quad .$$

Using methods of Chow/Robbins, results on elliptic functions and special series and estimations of Kuhlmann the upper bound is improved to

$$v^* \leq 0.6375 \quad .$$

J. TELGEN:

Operations Research in Banking

Banking, by its nature, is a conservative sector of business. The application of modern management techniques, including Operations Research, has a relatively short history. Its influence however is spreading rapidly. Today operational problems still form an essential part of OR applications in banking, but the emphasis is shifting towards tactical and strategical issues. This is linked with a

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development in which Decision Support Systems (DSS) play a very important role in the implementation of OR works. The developments skeched above will be demonstrated and illustrated with a number of examples from practice.

J. WESSELS §:

Approximations for Queues Arising from Disk I/O

In computer systems the work on a job at the central processor is interrupted several times for disk I/O. One can model the situation by a network of queues in which the central processor and the individual disk-units are the servers. Mean value analysis provides an elegant and efficient technique to solve such networks, at least under some extra requirements.
In our case there are two problems, namely the service time distributions at the disk-units are definitely non exponential and the I/O uses a system of channels which are not always avialable.
Based on the mean value approach an approximation method has been designed which appears to work well. In this method the non-availiability effect of the channels is incorporated iteratively. The method is quite efficient also.

§ joint work with R. Wijbrands.

U. ZIMMERMANN:

Sharing Problems

Sharing problems are separable optimization problems of the form $\min\{ \max_j f_j(x) \mid x \in P \}$ with share function $f_j: M \rightarrow N$, $j=1,2,..,n$, where M is a totally ordered abelian group and where N is a totally ordered set. Here we consider only sets P of feasible solutions, which are described by linear constraints. A quite general duality theorem can be proved when the level sets of the share functions are closed intervalls and when P satisfies a certain assumption which in particular is valid for linear constraints. Based on duality dual (threshold) methods can be formulated where the thresholds are calculated from knapsack sharing problems.

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When the sharefunctions are linear or bottleneck- share-functions, such dual methods can often be shown to be polynomial. For a large class of combinatorial optimization problems, i.e. submodular flow sharing problems, we also derive a primal method using negative circuits.

J. ZOWE:

On a 2nd Order Model in Nonsmooth, Convex Analysis

The problem of minimizing a nonsmooth convex function f is considered. An example is given which demonstrates that the standard smooth methods collapse if the minimum is attained at a kink. It is discussed how the standard tools from smooth convex analysis ( the subdifferential and the directional derivative ) have to be modified for nonsmooth f. A first and a second order model based on $\varepsilon$ - perturbations of these well known definitions are presented. The second order model yields a Newton direction as long as we are in the area where f is smooth and a decrease of at least $\varepsilon$ is guarantueed at every step in the non-smooth region of f.

Berichterstatter: P. Recht

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## Tagungsteilnehmer

Prof. Dr. A. Bachem
Mathematisches Institut
Uni Köln
Weyertal 86-90
5000 Köln 41

Prof. Dr. K.W. Gaede
Institut für Statistik und
Unternehmensforschung TU Münch.
Arcisstr. 21

8000 München

Prof. Dr. R.E. Burkhard
Institut für Mathematik
TU Graz
Kopernikusgasse 24

A-8010 Graz

Prof. Dr. W. Gaul
Institut für Entscheidungs-
theorie und Unternehmensforsch.
Uni Karlsruhe
Kaiserstr. 12
7500 Karlsruhe

Prof. Dr. Vladimir Demyanov
System and Decision Science Area
International Institute for
Applied Systems Analysis

A-2361 Laxenburg

Prof. Dr. M. Grötschel
Lehrstuhl für Angewandte Mathe-
matik II Uni Augsburg
Memminger Straße 6

8900 Augsburg

Prof. Dr. W. Domschke
-BWL und OR-
Bundeswehrhochschule
Postfach 85

2000 Hamburg

Prof. Dr. G. Hammer
Lehrstuhlfür Anwendung des OR
Uni Karlsruhe
Kaiserstr.12

7500 Karlsruhe 1

Prof. Dr. W. Eichhorn
Institut für Wirtschaftstheorie
und OR Uni Karlsruhe
Kaiserstr.12

7500 Karlsruhe

Priv. Doz.

Dr. E. Höpfinger

Kernforschungsanlage

517o Jülich

Prof. Dr. G. Feichtinger
Institut für Ökonometrie
und OR
Argentinierstr. 8/119

A-1040 Wien

Prof. Dr. A. Hordijk
University of Leiden
Department of Mathematics
Postbus 9512

2300 RA Leiden, Niederlande

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Prof. Dr. R. Horst
Fachbereich Mathematik/Inform.
Uni Oldenburg

2900 Oldenburg

Prof. Dr. H. König
Inst. f. Reine Mathematik der
Universität des Saarlandes

66oo Saarbrücken

Prof. Dr. D. Kadelka
Institut für Mathematische
Statistik Uni Karlsruhe
Kaiserstr. 12

7500 Karlsruhe

Prof. Dr. B. Korte
Inst. f. Ökonometrie u. OR
Universität Bonn
Nassestr. 2

53oo Bonn 1

Prof. Dr. P. Kall
Inst. für OR
Universität Zürich
Weinbergstr. 59

CH 8oo6 Zürich

Prof. Dr. P. Kosmol
Mathematisches Seminar
Universität Kiel
Olshausenstr.4o-6o

23oo Kiel

Prof. Dr. P. Kenderov
Inst. of Mathematics
Bulgarian Academy of Science
1o9o Sofia, Bulgarien

P.O. Box 373

Dr. R.M. Möhring
Lehrstuhl f. Informatik IV
RWTH Aachen
Templergraben 57

51oo Aachen

Prof. Dr. W. Knödel
Inst. für Informatik
Universität Stuttgart
Azenbergstr. 12

7ooo Stuttgart

Prof. Dr. O. Moeschlin
Fachbereich Mathematik
Fernuniversität Hagen
Roggenkamp 6

58oo Hagen

Prof. Dr. E. Köhler
Inst. f. Angewandte Mathematik
Universität Hamburg
Bundesstr. 55

2ooo Hamburg 13

Prof. Dr. M. Morlock
Inst. f. Wirtschaftsth. u. OR
Universität Karlsruhe
Kaiserstr. 12

75oo Karlsruhe

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Prof. Dr. K. Neumann
Inst. f. Wirtschaftsth. u. OR
Universität Karlsruhe
Kaiserstr. 12

75oo Karlsruhe

Dipl. Math. P. Recht
Inst. f. Statistik u. Math.
Wirtschaftsth. Uni Karlsruhe
Kaiserstr. 12

75oo Karlsruhe

Prof. Dr. H. Noltemeier
Lehrstuhl für Informatik
Universität Würzburg
Am Hubland

87oo Würzburg

Prof. Dr. S. Rolewicz
Instytut Matematyczny
Polckieij Academii Nauk
ul. Sniadeckich 8
skr.poczt. 137
PL - oo-95o Warszawa, Polen

Prof. Dr. IR.Jo van Nunen
Graduate School of Management
Poortweg 6-8

2612 PA Delft , Niederlande

Prof. Dr. J. Rosenmüller
Inst. f. Math. Wirtschafts-
forschung, Uni Bielefeld

48oo Bielefeld

Prof. Dr. W. Oettli
Lehrstuhl f. Mathematik VII
Universität Mannheim
Schloß

68oo Mannheim

Prof. Dr. M. Schäl
Inst. f. Angew. Mathematik
Universität Bonn
Wegelerstr. 6

53oo Bonn 1

Prof. Dr. D. Pallaschke
Inst. f. Statistik u. Math.
Wirtschaftsth. Uni Karlsruhe
Kaiserstr. 12

75oo Karlsruhe 1

Prof. Dr. R. Schaßberger
Institut für Mathematik der
TU Berlin
Straße des 17. Juni 135

1ooo Berlin 12

Dr. F.J. Radermacher

Universität Regensburg
Postfach 397

8400 Regensburg

Prof. Dr. H Schellhaas
Fachbereich Mathematik
TH Darmstadt
Kantplatz 1

61oo Darmstadt

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Prof. Dr. N. Schmitz
Inst. f. Math. Statistik
Universität Münster
Roxelerstr. 64

44oo Münster

Prof. Dr. J Wessels
Eindhoven University of Techn.
Department of Mathematics
P.O. Box 513
Eindhoven, Niederlande

Dr. J. Telgen
Rabobank Nederland
Laan van Eikenstein 9
Z1-G-17o

37o5 AR Zeist, Niederlande

Prof. Dr. U. Zimmermann
Mathematisches Institut
Universität Köln
Weyertal 86

5ooo Köln 41

Prof. Dr. W. Vogel
Inst. f. Angew. Mathematik
Universität Bonn
Wegelerstr. 6

53oo Bonn 1

Prof. Dr. J. Zowe
Lehrst. f. Angew. Mathematik
Universität Bayreuth
Postfach 3oo8

858o Bayreuth

Prof. Dr. H. Werner
Inst. f. Angew. Mathematik
Universität Bonn
Wegelerstr. 6

53oo Bonn 1

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