AD-A173 078 APPLICATION OF SURROGATE DUALITY TO DISCRETE OPTIMIZATION PROBLEMS(U) NORTH CAROLINA ARGICULTURAL AND TECHNICAL STATE UNIV GREENSBO.. B RAM ET AL. 1/1

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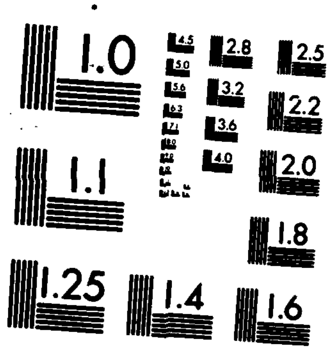

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Application of Surrogate Duality to Discrete Optimization Problems

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Balasubramanian Ram and Sanjiv Sarin

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17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Surrogate Duality, Optimization Problems Knapsack Problem, Constraint Aggregation

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

~~(i)~~ Size reduction (logical elimination of variables or constraints or elimination of redundant constraints) and constraint aggregation may all be viewed as preprocessing techniques for solving discrete optimization problems. It can be shown analytically that in the absence of constraint aggregation, size reduction leads to a poor linear programming relaxation value.

~~(ii)~~ A novel method was proposed to convert an equality knapsack problem into an equivalent inequality knapsack problem.

~~(iii)~~ The use of least-lower-bound based candidate problem selection in solving equality knapsacks was established.

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ARO 21880.5-MA-H

APPLICATION OF SURROGATE DUALITY TO DISCRETE OPTIMIZATION PROBLEMS

FINAL REPORT

by

Balasubramanian Ram
and
Sanjiv Sarin

August 15, 1986

U. S. Army Research Office
Contract No. DAAG29-84-G-0061

North Carolina Agricultural and Technical
State University

1. Statement of Problem

This research was concerned with some issues in employing surrogate duality concepts for solving discrete optimization problems of the following structure.

$$\begin{aligned} \text{Minimize} \quad & cx \\ \text{Subject to} \quad & Ax = b \\ & x \in X \end{aligned}$$

where $X = \{ \ell \leq x \leq u:$ x satisfies some integrality requirements $\}$. The set X is assumed to have some computationally convenient structure not possessed by the entire problem.

We consider the use of surrogate duality in solving the above problem by relaxing the equality constraints . This relates to the use of surrogate dual values as bounds in a branch-and-bound procedure. In a special case of the above problem, when all variables are discrete, computing a surrogate dual is equivalent to formulating an "aggregated" problem. The use of constraint aggregation for reducing problem size has been studied in the past. In this work, we concentrated on a specific aspect: that of investigating whether any logical size reduction has any effect on the effectiveness of constraint aggregation as a tool for solving the original problem.

For the type of problems studied, when all the constraints are relaxed, the resulting relaxation has the form of a knapsack problem, with an equality constraint.

While the inequality-constrained knapsack has been widely studied, the equality knapsack problem has received little attention. We addressed this problem in this research.

2. Summary of Results

The important results from this research are summarized as follows:

(i) Size reduction (logical elimination of variables or constraints or elimination of redundant constraints) and constraint aggregation may all be viewed as preprocessing techniques for solving discrete optimization problems. It can be shown analytically that in the absence of constraint aggregation, size reduction leads to a poor linear programming relaxation value. If the the constraints are aggregated after size reduction, the effect on the linear programming relaxation value and computational effort in solving the original problem cannot be evaluated analytically . Empirical results with randomly generated set partitioning problems indicate that there is no systematic effect. The recommendation based on this evidence is that, if constraint aggregation is to be employed, size reduction will not be computationally worthwhile.

(ii) A novel method was proposed to convert an equality knapsack problem into an equivalent inequality knapsack problem. The transformation is implemented very easily. The resulting inequality problem can be solved via any of the established methods for the inequality knapsack problem.

(iii) The use of least-lower-bound based candidate problem selection in solving equality knapsacks was established. The result of this was two-fold. We demonstrated the viability of using least-lower-bound (as opposed to the commonly used depth-first strategy). Second, an algorithm and a FORTRAN code for solving this problem was developed and tested. Our results indicate that this code is probably the best known currently (we have extensively compared our algorithm with a recently published one).

3. Conference Presentations

(i) Interaction of constraint aggregation and Size Reduction in Integer Programming. TIMS/ORSA Conference, April 29 - May 1, 1985, Boston, MA (abstract included in appendix).

(ii) A Least Lower Bound Approach for Solving the Equality Knapsack problem. TIMS/ORSA Conference, April 14-16, 1986, Los Angeles, CA (abstract included in appendix).

4. Publications/Technical Reports

(i) Effect of Size Reduction on Constraint Aggregation in Integer Programming. May 1985. Submitted to Opsearch. (Copy submitted to ARO, abstract included in appendix).

(ii) A Relationship between Equality and Inequality Knapsacks. May 1985. (Copy submitted to ARO, abstract included in appendix).

(iii) On Solving the Binary Knapsack Problem with Equality Constraint. March 1986. Submitted to IIE Transactions. (Copy submitted to ARO, abstract included in appendix).

(iv) An LLB-Based Algorithm for the 0-1 Equality Knapsack Problem. July 1986. Submitted to Mathematical Programming. (Copy submitted to ARO, abstract included in the appendix).

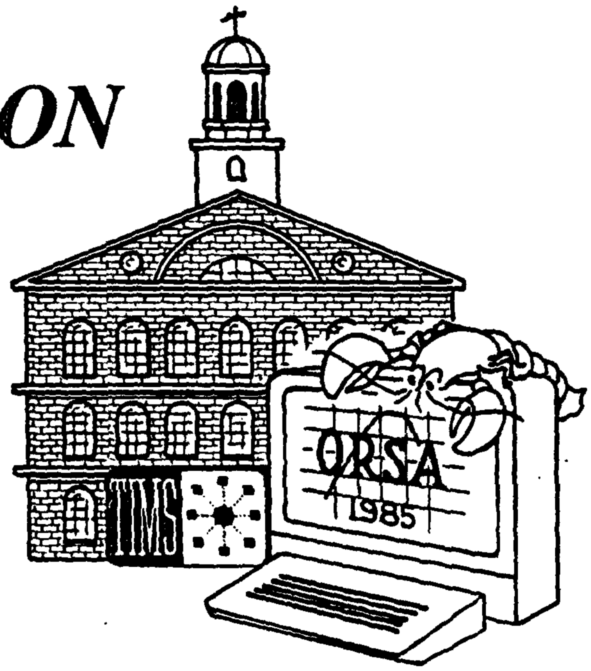
5. Degrees Earned by Personnel

Mr. Carl Daniel: Masters of Science degree in Industrial Engineering. Thesis title: A Least-Lower-Bound Approach to the Equality Knapsack Problem. (Copy of abstract included in the appendix).

APPENDIX

TIMS/ORSA 1985

BOSTON



Joint National Meeting

Sheraton Boston

April 29 – May 1, 1985

We have developed an interger program and a heuristic approach for scheduling N jobs on a flexible manufacturing machine such that the total set-up cost is minimized. This is in the context of a set-up cost in processing one job after another, where this cost depends on the total number of tool switches.

MB14.3 UPPER BOUNDS ON THE MAXIMUM MODULUS OF SUBDOMINANT EIGENVALUES OF NONNEGATIVE MATRIES, uriel G. Rothblum, Dept. of Industrial and Mgt. Engineering, Technion israel Institute of Technology, Haifa, Israel.

Upper bounds for the maximum modulus of the subdominant roots of square nonnegative, matrices are obtained. We provide a unified approach that yields or improves upon most of the bounds that have been obtained so far.

MONDAY AM — APRIL 29 — Liberty E
MB15 — 11:00-12:30

INTEGER PROGRAMS AND GRAPHS

Cluster: Mathematical Programming -- Combinatorial Optimization, Combinatorics, and Graph Theory

Chairman: Manfred Padberg, Department of Statistics and Operations Research, New York University, Washington Square, New York, NY 10003.

MB15.1 THE P-NARY NETWORK FLOW PROBLEM, Ellis L. Johnson, IBM Research, P.O. Box 218, Yorktown Heights, NY 10598.

We introduce the p-nary group problem and the special case of a network flow problem. A sub-additive characterization of facets of group subproblems is given and related to work of P. Seymour in the binary group case.

MB15.2 VALID INEQUALITIES AND FACETS FOR THE GENERALIZED ASSIGNMENT AND RELATED PROBLEMS, Elsie S. Gottlieb, Department of Statistics and Operations Research, New York University, Washington Square, New York, NY 10003, M. Padberg, Department of Statistics and Operations Research, New York University, Washington Square, New York, NY 10003, and M. R. Rao, Department of Statistics and Operations Research, New York University, Washington Square, New York, NY 10003.

The structural properties of the Generalized Assignment Problem (GAP) are studied. General properties of the facets of GAP are discussed and various classes of valid inequalities and facets based upon cycles, minimal covers and (1,k)-configurations are derived. We relate these results to the bin packing problem and a sequencing problem.

MB15.3 COMPUTATIONAL EXPERIMENTS WITH LOCATION PROBLEMS USING AUTOMATIC CONSTRAINT GENERATION, Jaume Barcelo Bugeda, Dept. d'Investigacio Operative i Estdistica, Facultat d'Informatica, Barcelona, Spain.

We report computational experience with the use of automatic constraint generation in the case of capacitated location problems involving between 30 and 40 plants and about 100 demand centers. For different types of model formulations different surrogate knapsack constraints for the constraint generation are investigated and found to substantially impact the actual numerical results.

MB15.4 THE PRODUCT MATRIX TRAVELING SALESMAN PROBLEM: AN APPLICATION AND SOLUTION HEURISTIC, Robert Plante, Krannert Graduate School, Purdue University, West Lafayette, IN 47907, Timothy Lowe, Krannert Graduate School, Purdue University, West Lafayette, IN 47907, and R. Chandrasekaran, School of Management, University of Texas at Dallas, Richardson, Texas 75080.

A special structure traveling saleman problem is presented. It is shown that the proposed model reduces to an asymmetric traveling salesman problem with a product matrix. The resulting model is applied to an important problem encountered in the 1st and 2nd state nozzle assembly of a gas turbine engine: the allocation of stator-vane airfoils to obtain a uniform gas flow.

MB15.5 INTERACTION OF CONSTRAINT AGGREGATION AND SIZE REDUCTION IN INTEGER PROGRAMMING, Balasubramanian Ram, North Carolina A & T State University, Greensboro, NC 27411, Sanjiv Sarin, North Carolina A & T State University, Greensboro, NC 27411, and Mark H. Karwan, State University of New York at Buffalo, Amherst, NY 14260.

Size reduction and constraint aggregation techniques may be employed to simplify integer programs. When constraint aggregation is used after size reduction, the efficiency of solving the aggregated problem may be affected by the extent of size reduction.

MONDAY AM APRIL 29 Liberty F
MB16 11:00-12:30

COMMUNICATION NETWORKS

Cluster: Mathematical Programming -- Network Optimization

Chairman: Kathleen A. Woolston, Rutgers University, 15 Belfast Ave., Hazlet, NJ 07730.

MB16.1 THE DESIGN OF MINIMUM COST CENTRALIZED NETWORKS WITH RELIABILITY CONSTRAINTS, Kathleen A. Woolston, Rutgers University, 15 Belfast Ave., Hazlet, NJ 07730, and Susan L. Albin, Rutgers University, Department of IE/OR, College of Engineering, P.O. Box 909, Piscataway, NJ 08854.

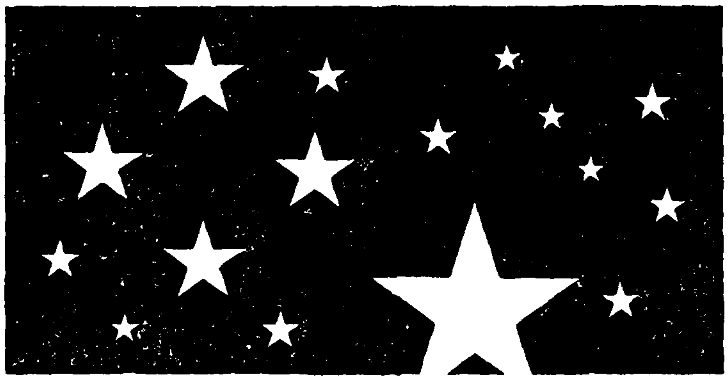
This paper describes an algorithm, called PANDA (Performance and Network Design Algorithm) which can be used for the design of minimum cost centralized communication networks with contraints on three network operation criteria: delay, availability, and reliability. Two starting topologies are described: star and minimum spanning three. PANDA is based on an algorithm developed by H. Frank.

MB16.2 NETWORKS FAILURE, WanSoo T. Rhee, the Ohio State University, Faculty of Management Sciences, Columbus, Oh 43210.

This paper studies random failure of networks when we know the probability of failure of each line but nothing about the intercorrelation of these failures. With no assumption on the structure of the network, we compute the probability that there still exists a path from the source to the sink after the worst possible network failure.

MB16.3 A DYNAMIC FLOW CONTROL MODEL FOR NETWORKS WITH MULTIPLE QUEUES AND SHARED SERVERS, Malachy Carey, Carnegie-Mellon University, Pittsburgh, PA 15213, and Ashok Srinivasan, Carnegie-Mellon University, Pittsburgh, PA 15213.

This paper develops a model for optimizing time-varying flows on congested networks having both sequential and parallel service options at nodes. Applications to road networks and communications networks are discussed and methods of solving the model are examined.



TIMS / ORSA
Los Angeles

Joint National Meeting
April 14-16, 1986

WD06.5 4:42 **A Methodology for Longitudinal Comparisons of Performance Levels of Professional Athletes.** James J. Cochran, *Wright State University, Dayton, OH 45435.* Patricia T. Boggs, *Wright State University, Dayton, OH 45435.*

A methodology for standardizing the performances of athletes competing under varying conditions attributable to the progression and refinement of professional sports over time is dveloped. A method for comparing the performance of athletes from different periods in the history of a particular sport will be presented.

WD07 Wednesday PM — 3:30-5:00 San Gabriel A

COMBINATORIAL OPTIMIZATION IV

Chairperson: Esther M. Arkin, *Department of Operations Research, Stanford University, Stanford, CA 94305.*

WD07.1 3:30 **Two Stage Hybrid Flowshop Scheduling Problem.** Jatinder N.D. Gupta, *Ball State University, Muncie, IN 47306.*

This paper describes the two stage flowshop problem when there are identical multiple machines at each stage and shows that the problem is NP-Complete. An efficient heuristic algorithm is developed for finding approximate solution of a special case when there is only one machine at stage 2. The effectiveness of the proposed heuristic algorithm in finding a minimum makespan schedule is empirically evaluated and found to increase with the increase in the number of jobs.

WD07.2 3:48 **A Least Lower Bound Approach for Solving the Equality Knapsack Problem.** Balasubramaniam Ram, *NC A&T State University, Greensboro, NC 27411.* Sanjiv Sarin, *NC AT&T State University, Greensboro, NC 27411.* Carl Daniel, *NC A&T State University, Greensboro, NC 27411.*

We demonstrate the use of Least Lower Bound strategy for selecting candidate problems during the solution of equality - constrained knapsack problems via branch-and-bound.

WD07.3 4:06 **An Enumerative Algorithm for General Quadratic Knapsack Problem.** Kamlesh Mathur, *Department of Operations Research, C.W.R.U., Cleveland, OH 44120.* Haravey Salkin, *Department of Operations Research, C.W.R.U., Cleveland, OH 44120.* Mohamed Djerdjour, *Department of Operations Research, C.W.R.U., Cleveland, OH 44120.*

This paper deals with quadratic knapsack problems with general integer variable. The algorithm uses various results obtained from the continuous/eigenvalue relaxation of the problem as implicit enumeration criteria.

WD07.4 4:24 **Scheduling Jobs With Fixed Start and End Times.** Esther M. Arkin, *Department of Operations Research, Stanford University, Stanford, CA 94305.* Ellen B. Silverberg, *Department of Operations Research, Stanford University, Stanford, CA 94305.*

We analyze a scheduling problem in which each job has a fixed start and end time and a value. An efficient algorithm is described which maximizes the value of jobs completed by k identical machines. With additional restrictions the problem becomes NP-complete.

WD07.5 4:42 **The Isolation Game and its Generalizations.** A.G. Robinson, *Math. Sciences, Johns Hopkins University, Baltimore, MD 21218.* A.J. Goldman, *Math. Sciences, Johns Hopkins University, Baltimore, MD 21218.*

We present analyses of Ringeisen's Isolation Game and some relevant combinatorial generalizations. The results support several interesting conjectures to the effect that most graphs are non- winnable by either player. Graphs yielding forced wins of any prescribed length are identified.

EFFECT OF SIZE REDUCTION ON CONSTRAINT AGGREGATION IN INTEGER PROGRAMMING

By

Sanjiv Sarin
and
Balasubramanian Ram

This research was supported by the U.S. Army Research Office Grant No: DAAG29-84-G-0061. The support is gratefully acknowledged.

Technical Report No: IE-SR-01
May, 1985

Department of Industrial Engineering
North Carolina A & T State University
Greensboro, NC 27411

ABSTRACT

Size reduction techniques involving logical reduction of constraints and variables and removal of redundant constraints are usually employed before solving a discrete optimization problem. Constraint aggregation is concerned with replacing a set of constraints with a single constraint while preserving exactly the same integer feasible region. It is well known that constraint aggregation schemes work only for equality constrained problems.

This research is concerned with determining if size reduction has any adverse effect on the efficiency of ensuing constraint aggregation based solution procedures for equality constrained integer programs. An effect that we particularly want to study is whether the linear programming relaxation bound to the aggregated problem deteriorates as a result of size reduction. Computational results indicate that such an effect is not present.

Keywords: Integer, Programming, Size Reduction, Constraint Aggregation

A RELATIONSHIP BETWEEN EQUALITY AND INEQUALITY KNAPSACKS

By

Sanjiv Sarin
and
Balasubramanian Ram

This research was supported by the U.S. Army Research Office Grant No: DAAG-29-84-G-0061. The support is gratefully acknowledged.

Technical Report No: IE-SR-02
May, 1985

Department of Industrial Engineering
North Carolina A & T State University
Greensboro, NC 27411

TITLE: A Relationship Between Equality and Inequality Knapsacks

AUTHORS: 1. Sanjiv Sarin
North Carolina Agricultural and Technical State University
2. B. Ram
North Carolina Agricultural and Technical State University
Greensboro, NC 27411

ABSTRACT: We show how an equality knapsack problem can be transformed into an inequality knapsack. We use this relationship to demonstrate the relative complexities of the two problems.

KEYWORDS: Integer Programming, knapsack problems, branch-and-bound

ACKNOWLEDGEMENT: The research reported here was supported in part by the U.S. Army Research Office Grant No. DAAG29-84-G-0061. This support is gratefully acknowledged

ADDRESS: Sanjiv Sarin
Assistant Professor
North Carolina Agricultural and Technical State University
Greensboro, NC 27411

TITLE: ON SOLVING THE BINARY KNAPSACK PROBLEM WITH EQUALITY CONSTRAINT

AUTHORS: (i) Sanjiv Sarin, Ph.D. Senior Member IIE
Department of Industrial Engineering
North Carolina A & T State University
Greensboro, NC 27411

(ii) Balasubramanian Ram, Ph.D., Senior Member IIE
Department of Industrial Engineering
North Carolina A & T State University
Greensboro, NC 27411

ACKNOWLEDGEMENT: The research reported here was supported in part by the U. S. Army Research Office Grant No. DAAG29-84-G-0061. This support is gratefully acknowledged.

ABSTRACT

We show how an equality constrained knapsack problem can be transformed to an equivalent inequality constrained knapsack problem. We use this relationship to propose a method for solving equality knapsack problems.

KEYWORDS: Integer Programming, Knapsack Problems, Branch-and-Bound.

AN LLB-BASED ALGORITHM

FOR

THE 0-1 EQUALITY KNAPSACK PROBLEM

By

Balasubramanian Ram
and
Sanjiv Sarin

Technical Report No. IE-RS02
July, 1986

Acknowledgment: The research reported here was supported in part by the U.S. Army Research Office Grant No. DAAG 29-84-G-0061. This support is gratefully acknowledged.

Department of Industrial Engineering
North Carolina Agricultural and Technical State University
Greensboro, NC 27411

Abstract

The 0-1 knapsack problem is a linear integer programming problem with a single constraint and binary variables. The knapsack problem with an inequality constraint has been widely studied and several efficient algorithms have been published. We consider the equality constraint, knapsack problem which has received relatively little attention. We describe an efficient branch-and-bound algorithm for this problem and present computational experience with up to 10,000 variables. An important feature of the algorithm is a least-lower-bound candidate problem selection discipline.

Keywords: Integer Programming, Knapsack Problems.

A LEAST-LOWER-BOUND APPROACH TO THE EQUALITY KNAPSACK PROBLEM

By

Carl L. Daniel

A thesis submitted to the Graduate Faculty of the North Carolina Agricultural and Technical State University in partial fulfillment of the requirements for the Degree of Master of Science in Industrial Engineering.

Greensboro, North Carolina

1986

Approved by:

Balasubramanian 2/28/86
Advisor

Chairperson of the Department

Dean of the School of Graduate Studies

ABSTRACT

We consider single-equality-constraint integer programming problems commonly referred to as integer equality Knapsack problems. Such a problem results when constraint aggregation is used to reduce problem-size in multiple-equality-constraint problems. The integer equality Knapsack problem can be solved using branch-and-bound methods. The branching discipline used in most branch-and-bound algorithms in integer programming is Last-In-First-Out or LIFO. We consider the Least-Lower-Bound or LLB approach here. We present an algorithm employing LLB branching. In branch-and-bound algorithms there are many ways to select a variable to branch on. We consider two ways with the LLB algorithm: The first involves branching in an order based on objective function coefficient-to-constraint coefficient ratios. The second method involves branching on the fractional variable in the linear programming relaxation solution at the current node. The efficiency of any branch-and-bound method depends on the ability to generate good feasible solutions within the branch-and-bound procedure. We consider heuristic methods to find such solutions to the integer equality Knapsack problem.

ACKNOWLEDGEMENTS

The author expresses his deepest thanks to God for providing him with all the resources necessary to complete this work. The resource which he is most grateful for is his thesis advisor, Dr. Balasubramanian Ram, for his helpful guidance, encouragement, and suggestions during the preparation of this thesis. The suggestions made by Dr. Sanjiv Sarin were very helpful as well.

Grateful acknowledgement is made to the Department of the Army: Project #DAAG29-84-G-0061 for the financial support. The assistance of the Industrial Engineering Department staff is also acknowledged with gratitude.

END

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