THIRD ANNUAL DONET MEETING 1996

May 7, 1996

1 PREFACE.

Welcome to the third Annual Meeting of the Discrete Optimization Network (DONET) at Stirin Castle in the Prague Area, May 19-24, 1996. This is the last of the DONET Annual meetings within the present framework of DONET. The previous annual meetings were held in Trento in 1993 and in London in 1995. These were of course not the only activities of the network and an interested reader may trace some of the other highlights (such as a conference in Annecy) in the activity report of 1995 which is included below. We would like to thank to Bruce Reed for providing us with it. We enclose a program of our 1996 meeting together with the abstracts of the talks. One can see that DONET contributed in an essential way to the development of Discrete Optimization in Europe especially by providing opportunities for the critical group of young researchers. We hope that we shall be able to continue and deepen our activity in the future. Finally we would like to thank to all the local coordinators for their support in preparing this conference.

Martin Loebl   Jaroslav Nešetřil

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3 DONET MEETING PRAGUE, MAY 19–24 1996.

INVITED SPEAKERS.

André Bouchet, University of Le Mans
Peter J. Cameron, Queen Mary and Westfield College (non-Donet participant)
Michele Conforti, University of Padova
Gerard Cornuejols, University of Toulouse and Carnegie Mellon University (non-Donet participant)
Bert Gerards, CWI, Amsterdam
Winfried Hochstaettler, University of Koeln (non-Donet participant)
Andras Frank, Eotvos University, Budapest
Monique Laurent, LIENS, Paris
Martin Loebl, Charles University, Prague
Andras Sebo, University Joseph Fourier, Grenoble
Bruce Shepherd, LSU, London
Bruno Simeone, University La Sapienza, Rome
Robin Thomas, Georgia Institute of Technology, Atlanta (non-Donet participant)
Carsten Thomassen, Technical University Danemark (non-Donet participant)
Dominic Welsh, University of Oxford

PROGRAM

Monday morning 9 a.m.
Robin Thomas
Bert Gerards
Colin McDiarmid

Monday afternoon 4 p.m.
Bruce Shepherd
Jens Vygen
Gautam Appa

Tuesday morning 9 a.m.
Dominic Welsh
Carsten Thomassen
Martin Loebl

Tuesday afternoon 4 p.m.
Monique Laurent
Winfried Hochstaettler
Willem Haemers

Wednesday morning 9 a.m.
Bruno Simeone
Andras Frank
Kyri Kilakos
Anjai Kapoor

Thursday morning 9 a.m.
Gerard Cornuejols
Michele Conforti
Andras Sebo

Thursday afternoon 4 p.m.
Denis Naddef
Sandor Fekete
Jorgen Bang-Jensen

Friday morning 9 a.m.
Andre Bouchet
Peter Cameron

4 DONET MEETING PRAGUE: THE ABSTRACTS.

Gautam Appa

Bimodular Network Matrices

LSU, London

Network matrices provide an important class of totally unimodular matrices which arise as a natural extension of the node-arc incidence matrices of directed graphs. They can be interpreted as arc-path incidence matrices in which each column represents the unique path between a pair of vertices in a directed tree graph, while rows represent the arcs of the tree graph. We provide a similar extension for the node-edge incidence matrices of undirected graphs. The node-edge incidence matrix (call it N) of an undirected graph, consisting of exactly two +1 entries in each column, has two important properties. First, N is totally bimodular, i.e., any square sub-matrix of N has a determinant 0 or $2k$ where k is any non- negative integer. Second, N is 2-integral. Non-singular submatrices of N contain, in general, decomposable balanced sub-matrices of type $R1$ with determinant $q1$ or type $R2$ with determinant $q2$. We identify the graphical structure of each type. $R1$ represents the incidence matrix of a tree graph augmented by one self-loop, while $R2$ turns out to be the incidence matrix of a connected graph with exactly one odd cycle of length at least three. We concentrate on the only new structure in this setting, viz., incidence matrices of connected graphs with exactly one odd cycle of length three or more. Let G represent a connected graph with n nodes and n edges, having exactly one such odd cycle. Then we define generalised paths/tours involving any two nodes of G, and write a bimodular network matrix, called BINET and denoted by B, as the edge-tour incidence matrix of these generalised tours. In general, elements of B are $0, q1$ and $q2$. We show that a binet matrix B is totally bimodular and 2-integral. We show connections to the ternary packing and covering problems. One surprising result shown is that one of the two five by five unimodular matrices, known not to be a network matrix, is a binet matrix.

Jorgen Bang-Jensen

A Polynomial Algorithm For The Hamiltonian Cycle Problem For Semicomplete Multipartite Digraphs

Odense University, Denmark

A *semicomplete digraph* is a digraph whose underlying graph is complete. A *semicomplete multipartite digraph* is a digraph that can be obtained from some semicomplete digraph D by choosing a spanning collection of vertex disjoint induced subgraphs of D and deleting all arcs inside each of these. When the number of subgraphs above is precisely two, we obtain the *semicomplete bipartite digraphs.* While the Hamiltonian cycle problem is very easy for semicomplete digraphs and relatively easy for semicomplete bipartite digraphs (in which case there is still a nice mathematical characterization), it has been an open problem for more than 10 years in the case of semicomplete multipartite digraphs. Recently the authors have proved (constructively) that there is a polynomial algorithm for the Hamiltonian cycle problem for semicomplete multipartite digraphs. In this talk we will give the necessary background and, if time permits, a very brief sketch of the algorithm.

André Bouchet

Tight Multimatroids

University of Le Mans

A multimatroid is a combinatorial structure that unifies the properties of delta-matroids and the properties of the Euler tours of 4-regular graphs. We originally introduced this structure to unify a theorem of Jackson on the existence of three orthogonal Euler tours in a 4-regular graph with a theorem of Edmonds on the existence of a covering of a matroid with a given number of independent sets.

Here we focus on the subclass of tight multimatroids. These multimatroids can be locally described by a simple graph, called fundamental graph, in the vicinity of any base. The 2-matroids associated to the even delta-matroids and the 3-matroids associated to 4-regular graphs are tight.

The transformations of a fundamental graph, when the base is changed, are compared to two local transformations of simple graphs: the local complementations and the edge-pivotings. By using these transformations it is possible to extend to tight multimatroids some of the connectivity properties known for matroids.

Peter J. Cameron

Derangements in Permutation Groups

Queen Mary and Westfield College

It is well known that the number of derangements in the symmetric group on n letters is very close to $n!/e$ for moderately large n. What about other permutation groups?

In the finite case, it follows from the orbit-counting lemma that the vector giving the probability that a random group element has i fixed points

($i = 1, \ldots, n$) is related to the vector whose i-th coordinate is the ratio of the number of orbits on i-tuples to the total number of i-tuples, by a binomial transformation. This can be used to find estimates for the proportion of derangements in some cases.

More interesting is the possibility of extending these results to infinite permutation groups. Sometimes, the above formalism provides an explicit number, but it is not clear what this number has to do with derangements. For example, for the infinite symmetric group we do indeed obtain 1/e, as expected; but for the group of order-preserving permutations of the rational numbers, we obtain 1/2.

Michele Conforti

A Theorem of Truemper about Wheels and Three-Path Configurations

University of Padova

Suppose one has to "sign" the edges of a graph with even an odd labels so that, for each chordless cycle H, the parity of the set of odd edges of H satisfies a given requirement (is even, is odd). Klaus Truemper has proven an important theorem about the minimal forbidden subgraphs for this property. We give a novel and easy proof for this result. We also describe several applications of this theorem: In particular,

-The characterization of Tutte of regular matroids and Reid for matroids representable over GF3

-The characterization of universally signable ghraphs

-The characterization of balanceable graphs

-The characterzation of the graph that can be signed so that every hole is either even or odd.

These results were jointly obtained with Cornuejols, Kapoor and Vuskovic.

Gerard Cornuejols

Ideal and Balanced Matrices

University of Toulouse and Carnegie Mellon University

A $0, 1$ matrix A is perfect if the polytope $\{x \leq 0 : Ax \leq 1\}$ is an integer polytope. It is ideal if $\{x \geq 0 : Ax \geq 1\}$ is an integer polyhedron. It is balanced if no square submatrix of odd order contains exactly two ones per row and per column. In this talk, we survey results and open problems about these and related classes of matrices.

Bert Gerards

The Matroids Representable Over The 4-element Field

CWI, Amsterdam

Together with Jim Geelen and Ajai Kapoor, we present the complete list of forbidden minors for GF(4)-representable matroids.

Willem Haemers

Disconnected vertex sets in graphs

Tilburg University

Let A and B be two disjoint vertex sets of a graph G such that there are no edges between A and B. We give an upper bound for $|A| \cdot |B|$ in terms of eigenvalues of matrix representations G. This leads to a lower bound for the bandwidth of G and to an upper bound for equidistant code pairs in an association scheme.

Winfried Hochstaettler

On Bases of Circuit Lattices

University of Koeln

This is joint work with Martin Loebl. Given a binary matrix B the circuit lattice of the corresponding binary matroid is the integer hull of the $0,1$-vectors in the kernel of B. We discuss a couple of observations concerning the following conjecture: The circuit lattice of a binary matroid has a basis of $0,1$-vectors or, in other words, the integer lattice of a binary code has a basis of codewords.

We relate this conjecture to a certain Sylvester-type Hadamard matrix M and prove a duality statement about submatrices of full row length.

Finally, we disprove a stronger version of the above conjecture, indicating, that it, if true, does not have a local character.

Sandor Fekete

Angle-Restricted Tours in the Plane

University of Koeln

Earlier this year, Aggarwal, Coppersmith, Khanna, Motwani, and Schieber showed that the so-called “Angular-Metric TSP” is NP-complete. In this problem, one has to find a Hamiltonian path for a given set of points in the Euclidean plane, such that the sum of the direction changes at each vertex along the tour is minimized. This result has important consequences for the problem of matroid parity, as it resolves the long-standing open question about the hardness of the weighted linear matroid parity problem in the affirmative.

The Angular-Metric TSP is closely related to the problem "Angle-Restricted Tour" (ART): For a given set $A \subseteq (-\pi; +\pi]$ of angles, we have to decide whether a set P of n points in the Euclidean plane allows a closed directed tour consisting of straight line segments, such that all angles between consecutive line segments are from the set A.

We present a variety of algorithmic and combinatorial results on this problem. In particular, we show that any finite set of at least five points in general position allows a "pseudoconvex" tour (i. e. a tour where all angles are nonnegative), and we derive a fast algorithm for constructing such a tour. Moreover, we give a complete classification (from the computational complexity point of view) for the special cases where the tour has to be part of the orthogonal grid.

The paper presented is joint work with Gerhard Woeginger (Graz).

Andras Frank

Orientations of Graphs And Submodular Flows

Eotvos University, Budapest

We briefly summarize the known link between submodular flows and orientation problems of undirected graphs. A simplified feasibility theorem will then be shown for submodular flows constrained by crossing submodular functions. As an application we derive an extension of a new orientation result of Nash-Williams.

Anjai Kapoor

Triangle Free Graphs That Are Odd-Signable

University of Padova

A graph is odd-signable if there exists an assignment of "odd" and "even" labels to the edges so that every hole has an odd number of odd edges. Graphs with no even holes are a subclass of this class. Triangle-free (TF) odd-signable graphs form a class of basic graphs for cap-free odd-signable graphs, which in turn are a basic class in the study of graphs with no even holes.

Here we give a decomposition theorem and recognition algorithm for TF odd-signable graphs. We also show that all TF odd-signable graphs can be constructed by a sequence of "ear additions". We make some conjectures regarding the description of the stable set polytope for these graphs.

These results were jointly obtained with Cornuejols, Conforti and Vuskovic.

Kyriakos Kilakos

Polytopes of Bounded Stable Sets

LSU London

The *t-stable set polytope* of a graph is the convex hull of incidence vectors of stable sets of cardinality at most t in the graph. For $t = 3$, we describe the facet defining inequalities of the t-stable set polytope of any bipartite graph G. In addition, we show that for any integral weighting on the vertices of G, the chromatic number of G (with respect to this weighting) is equal to the round up of its fractional chromatic number plus one.

More generally, for any integer t, we discuss facet defining inequalities of the t-stable set polytope of bipartite graphs.

Monique Laurent

In memory of Svata Poljak: Positive Semidefinite Programming For Max-Cut, Geometric Results

LIENS, Paris

This talk is devoted to results obtained jointly with Svata Poljak on the geometry of the semidefinite relaxation for the max-cut problem. Svata had, in fact, introduced me to this topic in September 1993 at the occasion of a one month visit in Paris and our collaboration continued thereafter.

Positive semidefinite programming has been applied successfully for several combinatorial optimization problems, in particular, for the maximum stable set problem in perfect graphs (by the work of Grötschel, Lovász and Schrijver) and, more recently, for the max-cut problem. Goemans and Williamson have shown how to design good and efficient approximation algorithms for max-cut by optimizing over the *elliptope* $\mathcal{E}_n$, which is the set of $n \times n$ symmetric positive semidefinite matrices with diagonal entries one. Since then, it has been recognized that similar techniques apply for several other problems (such as max 2-sat, graph coloring, max k-cut, or maximum bisection problems) using the elliptope with possibly some additional linear constraints.

Our work with Svata focused, in particular, on trying to understand the geometry of the elliptope $\mathcal{E}_n$. In particular, we described its vertices (i.e., the points with full dimensional normal cone; they are precisely the cuts) and the spectrum of its face dimensions (and for its polyhedral faces as well). We also considered the following further aspects: link with the TH-body underlying the positive semidefinite relaxation for the maximum stable set problem, possible tightening of the elliptope using the gap inequalities, description in closed form of projections of the elliptope for certain classes of graphs (in connection with completion problems for positive semidefinite matrices in linear algebra).

Martin Loebl

On Pfaffian Orientations of Graphs

Charles University, Prague

This is joint work with Anna Galluccio. We present a theory of Pfaffian orientations of graphs and their linear combinations, proposed by Kasteleyn in the beginning of the 60's. It has strong consequences for the enumeration of perfect matchings, for the Max Cut problem and the Ising Spin Glasses. We will discuss separately the problem of Pfaffian orientations of bipartite graphs which is equivalent to the even cycle problem.

Colin McDiarmid

Colouring Proximity Graphs in The Plane

University of Oxford

Given a set S of points in the plane, and given $d > 0$, let $G(S, d)$ denote the graph with vertex set S and with distinct vertices adjacent whenever the Euclidean distance between them is less than d. We are interested in colouring such 'proximity' or 'interference' graphs. One application where this problem arises is in the design of mobile telephone networks, when we need to assign radio frequency bands (colours) to transmitters (points in S) to avoid interference. We find for example that, if the set S has density σ, then the chromatic number χ satisfies $\chi(G(S,d))/d^2 \to \sigma\sqrt{3}/2$ as $d \to \infty$. This is joint work with Bruce Reed.

Denis Naddef

Discovering The TSP Polytope

University Joseph Fourier, Grenoble

In this talk, which is inspired greatly by discussions with Yves Pochet of CORE, I will try to give you a feeling of what most of the known valid inequalities for that polytope say. I will end by my favorite conjecture on that polytope.

Rudi Pendavingh

A Polynomial Time Algorithm For Bibranching

University of Amsterdam

This is joint work with J. Keijsper. Let $D = (V, A)$ be a digraph, $W \subset V$ a subset of its vertices. A *bibranching* is a set $B \subset A$ such that

1. for all $v \in W$, B contains a directed path from v to a vertex in $V \setminus W$, and
2. for all $v \in V \setminus W$, B contains a directed path from a vertex in W to v.

For $W = \{r\}$, a bibranching is exactly an r-branching, i.e. a directed tree rooted at r. Given a bipartite graph, let W be one of the colour classes and orient all arcs away from W. A set of arcs is a bibranching of the resulting digraph iff it is an edge cover of the original graph.

Now let w be a positive integer weight function on the arrow set. Then, the linear programming duality equation for minimum weight bibranching has integral optimum solutions. We will present a primal-dual algorithm for constructing a bibranching of minimum weight in polynomial time.

Andras Sebo

Gaps and Jumps

University Joseph Fourier, Grenoble

Jump systems have been recently defined by Bouchet and Cunningham, as a generalization of matroids (and delta-matroids). The convex hulls of these constitute the most general class of polyhedra for which the greedy algorithm works, and include integral (generalized) polymatroids; on the other hand they do not contain all integer vectors of their convex hull, and those which they do not contain – called *gaps* – have a particular shape, and allow to include problems like the existence of graph factors and several tempting open problems Jump systems are determined by one simple axiom.

In the talk I would first like to explain the fundamental results of Lovász proved at a meeting last summer (partially supported by DONET). These show that jump systems provide a framework for several important results and problems of combinatorial optimization.

Then I will show some results of Cunningham, Geelen and Sebő, using Lovász's toolbox and requiring further work. For instance I will show that every gap is the average of two closest points of the jump system, and derive several consequences.

Bruce Shepherd

A Node capacitated routing problem arising in local optical networks

LSU, London

We discuss several problems arising in network routing and design. In particular we consider a node-capacitated routing problem related to ring networks of passive optical networks.

Bruno Simeone

Generation of all k-partitions of an n-set in amortized constant time per partition

University La Sapienza, Rome

This is a joint work with Fabio Grasso. The present paper deals with the sequential generation of all k-partitions of an n-set, for a fixed $1 \leq k \leq n$. The fastest known algorithm for this task is due to Ehrlich: it takes $O(k)$ time per partition. Here we propose another algorithm which takes only amortised constant time per partition. The algorithm is a modification of a previous procedure described by Nijenhuis and Wilf. We give an implementation which makes use of simple data structures, requires only $2n + k + c$ memory locations, where c is a small constant, and achieves the above time bound. Such bound is established through a careful analysis of the changes between any two consecutive partitions.

L. A. Székely

The number of nucleotide sites needed to accurately reconstruct large evolutionary trees

Eotvos University, Budapest

This is joint work with M. A. Steel and P. L. Erdős. Biologists seek to reconstruct evolutionary trees for increasing numbers of species, n, from aligned genetic sequences. How fast the sequence length N must grow, as a function of n, in order to accurately recover the underlying tree with probability $1 - \epsilon$, if the sequences evolve according to simple stochastic models of nucleotide substitution? We show that for certain models, the sequence length N can grow surprisingly slowly with n (sublinearly for a wide range parameters, and even as a power of $\log n$ in a narrow range, which roughly meets the lower bound from information theory). By contrast, a more traditional technique (maximum compatibility) provably requires N to grow faster than linearly in n. Our approach is based on a new, and computationally efficient approach for reconstructing phylogenetic trees from aligned DNA sequences.

Robin Thomas

Packing directed circuits

Georgia Institute of Technology

In joint work with Bruce Reed, Neil Robertson and Paul Seymour we have proved a conjecture of Younger, that for every integer $n \geq 0$ there exists an integer $t \geq 0$ such that for every digraph G, either G has n vertex-disjoint directed circuits, or G can be made acyclic by deleting at most t vertices. In this talk I will give motivation for the conjecture, and outline the proof.

Carsten Thomassen

The Graph Genus Problem

Technical University, Danemark

The graph genus problem is that of deciding if a given graph can be embedded in the surface obtained from the sphere by adding g handles. This problem was mentioned in the book on NP-completeness by Garey and Johnson. Special variants for triangulations and cubic graphs were suggested be Ringel and Richter, respectively. In this talk we survey constructions showing that these problems are NP-complete. We also discuss the maximum genus problem and double tracings of graphs for which there exist polynomial time algorithms.

Jens Vygen

A Linear–Time Algorithm for Partitioning 2-Dimensional Pointsets

University of Bonn

At the DONET Conference 1995 in London I introduced a theorem describing the structure of the optimum solutions of a crucial problem during VLSI-placement. I mentioned that this leads to a linear–time algorithm at least for a special case. Today I can show how the results can be extended to the general case.

The mathematical description of the problem is as follows: Given a finite set S of points in the plane, weights $w : S \to R_+$, and capacities

$\kappa_0, \kappa_1, \kappa_2, \kappa_3$ of the four quadrants, we are looking for a fractional partition $g : S \times \{0,1,2,3\} \to [0,1]$ with $\sum_{i=0}^{3} g(s,i) = 1$ for all $s \in S$, such that the capacity constraints $\sum_{f(s)=i} w(s) \leq \kappa_i$ $(i = 0,1,2,3)$ are met and the total movement $\sum_{s\in S} \sum_{i=0}^{3} w(s)g(s,i)d(s,Q_i)$ is minimized. Here Q_i denotes the i-th quadrant and d denotes the L_1-distance.

Dominic Welsh

Polynomial time randomised approximation schemes for Tutte-Gröthendieck invariants

University of Oxford

The Tutte polynomial $T(G;x,y)$ of a graph G encodes numerous interesting combinatorial quantities associated with the graph. Its evaluation in various points in the (x,y) plane give the number of spanning forests of the graph, the number of its strongly connected orientations, the number of its proper k-colourings, the (all terminal) reliability probability of the graph, and various other invariants the exact computation of each of which is well known to be $\#P$-hard. Here I survey the problem of finding a fully polynomial randomised approximation schemes for approximating the value of $T(G;x,y)$. In particular I shall describe recent results obtained with Noga Alon and Alan Frieze which will give an fpras for evaluating T for any dense graph G, that is, any graph on n vertices whose minimum degree is $\Omega(n)$, whenever $x \geq 1$ and $y \geq 1$, and in various additional points. This region includes evaluations of reliability and partition functions of the ferromagnetic Q-state Potts model, and extends to linear matroids where T specialises to the weight enumerator of linear codes.

5 DONET MEETING PRAGUE: THE LIST OF PARTICIPANTS.

Karen Aaardal, University of Utrecht
Christopher Anhalt, University of Bonn
Gautam Appa, LSU, London
Jorgen Bang-Jensen, Odense University, Denmark
(non-Donet participant)
Eric Bartels, University of Oxford
V.L.Beresnev, University of Novosibirsk
(non-Donet participant)
Adrian Bondy, University of Lion
André Bouchet, University of Le Mans
Michel Burlet, University Joseph Fourier, Grenoble
Peter J. Cameron, Queen Mary and Westfield College
(non-Donet participant)
Ondrej Cepek, Charles University, Prague
Michele Conforti, University of Padova
Gerard Cornuejols, University of Toulouse and
Carnegie Mellon University (non-Donet participant)
Andrea De Vitis, University La Sapienza, Rome
Reinhard Diestel, University of Chemnitz
(non-Donet participant)
Sandor Fekete, University of Koeln
(non-Donet participant)
Jean Fonlupt, University Paris 6
Paolo Franciosa, University La Sapienza, Roma
Andras Frank, Eotvos University, Budapest
Bert Gerards, CWI, Amsterdam
Roberto Giaccio, University La Sapienza, Roma
Rebecca Gower, University of Oxford
Willem Haemers, Tilburg University
Jan van den Heuvel, LSU, London
Petr Hlineny, Charles University, Prague
Winfried Hochstaettler, University of Koeln
(non-Donet participant)
Stan van Hoesel, University of Limburg
Hein van der Holst, CWI Amsterdam
Tibor Jordan, Eotvos University, Budapest
Anjai Kapoor, University of Padova
Judith Keijsper, University of Amsterdam
Kyriakos Kilakos, LSU, London

Martin Klazar, Charles University, Prague
Bernhard Korte, University of Bonn
Jan Kratochvil, Charles University, Prague
Monique Laurent, LIENS, Paris
Robert Leese, University of Oxford
Martin Loebl, Charles University, Prague
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Criel Merino, University of Oxford
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Jaroslav Nesetril, Charles University, Prague
Steven Noble, University of Oxford
Rudi Pendavingh, University of Amsterdam
Aline Pennisi, University La Sapienza, Rome
Myriam Preissmann, University Joseph Fourier, Grenoble
Federica Ricca, University La Sapienza, Rome
Andre Rohe, University of Bonn
Irasema Sarmiento, University of Oxford
Andras Sebo, University Joseph Fourier, Grenoble
Bruce Shepherd, LSU, London
Mark Shepherd, University of Oxford
Bruno Simeone, University La Sapienza, Rome
Stefano Smriglio, University La Sapienza, Rome
Leen Stougie, University of Amsterdam
Laszlo Szekely, Eotvos University, Budapest
Robin Thomas, Georgia Institute of Technology, Atlanta
(non-Donet participant)
Carsten Thomassen, Technical University Danemark
(non-Donet participant)
Zsolt Tuza, Eotvos University, Budapest
Pavel Valtr, Charles University, Prague
Jens Vygen, University of Bonn
Dominic Welsh, University of Oxford

6 DONET ANNUAL REPORT, 1995.

Overview

The DO-Net network has the following three long term objectives:

- further development of the theory and methods of discrete optimization
- providing a European center of excellence for the training of young post-doctoral researchers
- the development of algorithms and software for specific discrete optimization problems.

The immediate aim of this contract is to solidly establish the network via intensive workng periods which have both a training component and a collaborative research component. The initial contract called for two such periods each year, both of a duration between two weeks and one month.

Two such periods were organized this year. However, a week-long duration seemed more appropriate given the difficulty of scheduling longer meetings.

The first meeting was held in London, England during June and was also funded by the London Mathematical Society. This meeting focused on the application of discrete mathematics to practical problems. Researchers reported on work in diverse areas including: railway time-tabling, VLSI chip design, aircraft crew scheduling, fiber optic networks, and currency markets. As at all DONET meetings, substantial blocks of time were set aside for collaborative research, and the seeds were sown for a number of joint projects, leading to at least three joint papers.

The second meeting, which was held in Annecy, France during June and was also funded by the Universite de Lyon, had a different flavour. Its focus was a 25 year old conjecture concerning routing in networks. This conjecture is intimately related to recent fundamental breakthroughs in routing theory (due to Robertson and Seymour). The conjecture had been studied by researchers throughout the network with partial success (see e.g. the joint paper of Reed and Shepherd on this topic which is listed below). The purpose of the Annecy meeting was to bring together a small number of researchers from throughout the network (and around the world, with funding provided by the Universite de Lyon) to study the problem. The conference was a huge success as the conjecture was proven true. Hopefully, the techniques used will lead to further breakthroughs in this fertile area.

Institutes throughout the network are also beginning to cooperate on more applied problems. We mention cellular telephone networks as a specific example. Oxford University using money made available by industrial sponsors, recently appointed a post-doctoral fellow to study problems related to this new technology. Dr Kilakos, a DONET post-doctoral fellow recently appointed at the LSE also has experience in this area. Researchers from France visiting Oxford were drawn into the group. Cooperation between these three groups continues to grow, and has already resulted in a joint technical report. Both the University of Oxford and LSE have strong links to the telecommunications industry. In particular, Dr. Shepherd at the LSE works as a consultant for British Telecom. Thus, the practicality of the ideas generated by DONET researchers can be tested quickly, and if appropriate the ideas can be implemented.

Joint research was also carried out in a number of other areas, as the attached list of joint papers shows.

Also attached are participant lists for the two conferences, a table indicating the size of each team in the network, and a list of visits between member institutions funded from the grant.

The Teams of The Network

Institution	Researchers
London School of Economics	9
University of Oxford	5
CWI, Amsterdam	6
Universitat Bonn	8
Universite Paris 6	8
Universite Joseph Fourier	6
University La Sapienza, Rome	8
Charles University,Prague	5
Eotvos University, Budapest	9

Joint Papers

- G. Ausiello, E. Feuerstein, S. Leonardi, L. Stougie, and M. Talamo,. *Competitive algorithms for the on-line travelling salesman*, preprint.
- Y. Bartal, S. Leonardi, A. Marchetti Spaccamela, J. Sgall, and L. Stougie, *Multiprocessor scheduling with rejection*, preprint.
- Y. Bartal, S. Leonardi, A. Marchetti Spaccamela, J. Sgall,and L. Stougie, *Multiprocessor scheduling with rejection (extended abstract).* Proceedings of the Seventh Annual ACM-SIAM Symposium on Discrete Algorithms (SODA 96), January 28-30, Atlanta, Georgia, USA, 1996.
- G. Brightwell and P. Franciosa, *On the Boolean dimension of spherical orders,*, preprint.
- A. Frank, A. Karzanov, and A. Sebo, *On integer multi-flow maximization*, preprint.
- A. Galluccio and M. Loebl, *Cycles of prescribed modularity*, preprint.
- A. Gerards, and A. Sebo, *Multiflows, the cut condition and Klein's bottle*, preprint.
- A. Gerards and F.B. Shepherd, *Graphs with all subgraphs t-perfect*, preprint.
- B. Korte and J. Nesetril, *Vojtech Jarnik's works in combinatorial optimization*, preprint.
- J. Kratochvil and A. Sebo, *Coloring precolored perfect graphs*, preprint.
- S. Leonardi, A. Marchetti Spaccamela, and L. Stougie, *On-line scheduling with possible rejection of jobs*, preprint.
- C. Linhares-Sales, F. Maffray and B. Reed, *On planar perfectly contractile graphs*, preprint.
- C. Linhares-Sales, F. Maffray and B. Reed, *On planar strict quasi-parity graphs*, preprint.
- C.McDiarmid and B. Reed, *Colouring and Euclidean Distance*,preprint.
- B. Reed and F.B Shepherd, *The Gallai-Younger conjecture holds for planar graphs*, preprint.
- B. Reed, N. Robertson, P. Seymour, and R. Thomas, *Packing directed circuits*, preprint.

Visits

Attendance at intensive working periods is listed separately.

- A. Benczur, Budapest-Grenoble, five days.
- G. Brightwell, London-Budapest, eleven days.
- T. Jordan, Amsterdam-Grenoble, five days.
- R. Hein, Amsterdam-Grenoble, five days.
- A. Frank, Budapest-Grenoble, five days.
- A. Frank, Budapest-Bonn, eleven days.
- J. Fonlupt, Paris-Bonn, one month,
- J. Fonlupt, Paris-London, one week,
- B. Korte, Bonn-Prague, five days.
- T. Kaiser, Prague-Budapest, five days.
- J. Matousek, Prague-Budapest, five days.
- J. Matousek, Prague-Roma, ten days.
- J. Nesetril, Prague-Bonn, one year.
- J. Nesetril, Bonn-Paris, three days.
- J. Nesetril, Bonn-Rome, three days.
- B. Reed, Paris - Bonn, two weeks.
- B. Reed, Paris - Oxford, six weeks.
- A. Schrijver, Amsterdam-Paris, two weeks.
- B. Shepherd, London-Amsterdam, five weeks.
- B. Shepherd, London-Bonn, five days.
- L. Stougie, Amsterdam-Rome, six weeks.
- J. Vygen, Bonn-Budapest, eleven days.
- Z. Szigeti, Budapest-Grenoble, five days.

Participants list: Donet Meeting, London, June 26-30, 1995

K. Aardal, Amsterdam
C. Albrecht, Bonn
S. Amin, BT Laboratories (non-Donet participant)
C. Anhalt, Bonn
Martin Anthony, LSE
Gautum Appa, LSE
D. Applegate, ATT Bell Labs (non-Donet participant).
J. Bang-Jensen, Odense University (non-Donet participant)
F. Barahona, IBM Research (non-Donet participant)
E. Bartels, Oxford
A. Benczur, Budapest
Thomas Bending, Queen Mary and Westfield College
(non-Donet participant)
Norman Biggs, LSE
Graham Brightwell, LSE
N. Christofides, Imperial College (non-Donet participant)
W. Cook, Bonn
W. Cunningham, Grenoble(visitor)
C. Van Eijl, Eindhoven (non-Donet participant)
G. Elekes, Budapest
S. Fekete, Koln (non-Donet participant)
M. Fischetti, DEI, Padua
J. Fonlupt, Paris
C. De Francesco, Padua
A. Frank, Budapest
M.X. Goemans, MIT (non-Donet participant)
C. Hurkens, Eiendhoven(non-Donet participant)
T. Jordan, Budapest
J. Keijsper, Amsterdam
Z. Kira'ly, Budapest
B. Korte, Bonn
D. LeSaint, BT Laboratories (non-Donet participant)
M. Loebl, Prague
C. Mannino, Rome
R. Marsten, Atlanta, USA (non-Donet participant)
A. Mascis, Rome
J. Matoussek, Prague
C. McDiarmid, Oxford
M. Molloy, Paris(visitor)
D. Naddef, Grenoble
G.L. Nemhauser, Atlanta (non-Donet participant)
J. Nesetril, Prague

S. Noble, Oxford
G. Oriolo, Rome
D. Pacciarelli, Rome
A. Pacifici, Rome
R. Pendavingh, Amsterdam
S. Powell, LSE
M. Preissmann, Grenoble
W.R. Pulleyblank, IBM research (non-Donet participant)
B. Reed, Paris
P. Riva, LSE
A. Rohe, Bonn
F. Rossi,Rome
A. Schrijver, Amsterdam
A. Sebo, Grenoble
B. Shepherd, LSE
B. Simeone, Rome
R. Succi, Rome
Z. Szigeti, Budapest
M. Trick Carnegie Mellon University (non-Donet participant)
P. Valtr, Prague
J. Vygen, Bonn

Participants list: Donet Meeting, Annecy, June 16-23, 1995

N. Alon, Tel-Aviv University
A. Bondy, Universite de Lyon
A. Gerards, Amsterdam
W. McCuiag, University of Toronto
C. McDiarmid, Oxford
M. Molloy, Paris (visitor)
B. Reed, Paris
P. Seymour, Bell Communications Research
B. Shepherd, LSE
R. Thomas, Paris
S. Thomasse, Universite de Lyon
S. Vempala, Carnegie Mellon University