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Binary Clutters and Multicommodity Flows

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Abstract. In this short survey, we consider three classes of binary clutters, namely ideal clutters, Mengerian clutters, and cycling clutters. We will see that these classes are well understood for clutters of odd circuits of graphs. This has important applications for multicommodity flows.

1. Introduction

The purpose of this survey is to present some results (and extensions) on multicommodity flows in undirected graphs which give sufficient conditions for the existence of fractional, integer, or $\frac{1}{2}$-integer multicommodity flows. These results state that for certain primal-dual pairs of linear programs, we can sometimes find optimum integer solution for either the primal or both the primal and the dual. It is natural to consider the same type of primal-dual linear programs in a more general context. This leads to the study of special classes of binary clutters called, ideal, cycling, and Mengerian.

The paper is organized as follows: we first review definitions on binary clutters. We state a theorem characterizing Mengerian binary clutters and state conjectures which would characterize ideal and cycling binary clutters. In the following section we focus on a class of clutters which arises by considering the families of odd circuits of signed graphs. We show that we can characterize the ideal, cycling, and Mengerian properties for that class of clutters and show the relation with multicommodity flows. In the last section we state various generalizations to larger classes of clutters including a conjecture which would generalize the 4-colour theorem.

2. Binary Clutters

A *clutter* $\mathcal{H}$ is a finite family of sets, over some finite ground set $E(\mathcal{H})$, with the property that no set of $\mathcal{H}$ contains, or is equal to, another set of $\mathcal{H}$. The *blocker* $b(\mathcal{H})$ of $\mathcal{H}$ is the clutter defined as follows: $E(b(\mathcal{H})) := E(\mathcal{H})$ and $b(\mathcal{H})$ is the set of inclusion-wise minimal members of $\{B : B \cap C \neq \emptyset,\ \forall C \in \mathcal{H}\}$. It is well known that for a clutter, $\mathcal{H}$, $b(b(\mathcal{H}))=\mathcal{H}$. A clutter is said to be *binary* if, for any $C_1, C_2, C_3 \in \mathcal{H}$, their symmetric difference $C_1 \Delta C_2 \Delta C_3$ contains, or is equal to, a set of $\mathcal{H}$. Equivalently (Lehman [11]), $\mathcal{H}$ is binary if, for every $C \in \mathcal{H}$ and $B \in b(\mathcal{H})$, $|C \cap B|$ is odd. In the following discussion we will assume that $\mathcal{H}$ is a binary clutter. Consider the following linear program:

$$\begin{array}{lll} \text{minimize} \bullet\ (w_e x_e : e \in E(\mathcal{H})) & & \\ \text{subject to} & & \\ \quad x(C) \geq 1 & C \in \mathcal{H} & \text{(P)} \\ \quad x_e \geq 0 & e \in E(\mathcal{H}) & \end{array}$$

and its dual

$$\begin{array}{lll} \text{maximize} \bullet\ (y_C : C \in \mathcal{H}) & & \\ \text{subject to} & & \\ \quad \bullet\ (y_C : e \in C \in \mathcal{H})'' \ w_e & e \in E(\mathcal{H}) & \text{(D)} \\ \quad y_C \geq 0 & C \in \mathcal{H}. & \end{array}$$

We say that $\mathcal{H}$ is *ideal* if for all (integer) $w \in \mathbb{Z}_+^{E(\mathcal{H})}$ there is an optimum integer solution to (P). This concept is also known under the name of *width-length property, weak Max Flow Min Cut property* or $\mathbb{Q}$+-*MFMC property*. We say that $\mathcal{H}$ is *Mengerian* if for all $w \in \mathbb{Z}_+^{E(\mathcal{H})}$ there is an optimum integer solution to (P) and to (D). These clutters also known as clutters with the (strong) *Max Flow Min Cut property* or $\mathbb{Z}$+-*MFMC property*. We say that weights $w \in \mathbb{Z}_+^{E(\mathcal{H})}$ are *Eulerian* if for all pairs $D, D' \in b(\mathcal{H})$ we have that $w(D \Delta D')$ is even (where Δ denotes the symmetric difference of two sets). We say that $\mathcal{H}$ is *cycling* if for all Eulerian $w \in \mathbb{Z}_+^{E(\mathcal{H})}$ there is an optimum integer solution to (P) and to (D). By definition every Mengerian clutter is cycling. Every cycling clutter $\mathcal{H}$ is ideal. Indeed consider a cycling clutter $\mathcal{H}$ and any $w \in \mathbb{Z}^{E(\mathcal{H})}$. Since $2w$ is Eulerian there exist an optimum integer solution to (P) for $2w$. But that solution is also optimum for w. Thus Mengerian clutters are cycling and cycling clutters are ideal. We next show that the inclusions are all strict.

Let $\mathcal{Q}_6$ denote the clutter, where $E(\mathcal{Q}_6)$ correspond to the edges of the complete graph K_4 and the elements of K_4 are each of the triangles of K_4. Then $\mathcal{Q}_6$ is not Mengerian. Indeed suppose w is the vector of all ones. Then an optimum integer solution to (P) has value 2 (it corresponds to a set of edges which intersect all triangles of K_4) and an integer solution to (D) has value 1 (it corresponds to a set of disjoint triangles). Theorem 3.3 will imply that $\mathcal{Q}_6$

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is cycling. Let $\mathcal{P}_{10}$ be the clutter whose ground set correspond to the Petersen graph and where elements of $\mathcal{P}_{10}$ correspond to the postman sets of the Petersen graph (i.e. sets of edges which induce a graph whose odd degree vertices correspond to the odd degree vertices of the Petersen graph). It can be readily checked that $\mathcal{P}_{10}$ is ideal but not cycling.

Not every clutter is ideal. Let $\mathcal{O}_{K_5}$ denote the clutter, where $E(\mathcal{O}_{K_5})$ correspond to the edges of the complete graph K_5 and the elements of K_5 are each of the odd circuits of K_5 (the triangles or the circuits of length five). Then $\mathcal{O}_{K_5}$ is not ideal. Indeed suppose w is the vector of all ones. For (P) assign each variable x_e the value $\frac{1}{3}$ and for (D) assign each variable y corresponding to a triangle the value $\frac{1}{3}$ and all other variables the value zero. Then x and y are feasible variables for respectively (P) and (D) which both have value $\frac{10}{3}$. Hence, there is not optimum integer solution for (P). Lehman [12] showed that if a clutter is ideal, then so is its blocker. Since $\mathcal{O}_{K_5}$ is not ideal, neither is its blocker $b(\mathcal{O}_{K_5})$. The ground set of the clutter $\mathcal{L}_{F_7}$ are the elements {1,2,3,4,5,6,7} of the Fano matroid and the sets in $\mathcal{L}_{F_7}$ are the circuits of length three (the lines) of the Fano matroid, i.e.,

$$\mathcal{L}_{F_7} := \{\{1,3,5\}, \{1,4,6\}, \{2,3,6\}, \{2,4,5\}, \{1,2,7\}, \{3,4,7\}, \{5,6,7\}\}.$$

It can be readily checked that $\mathcal{L}_{F_7}$ is not ideal either. Note the blocker of $\mathcal{L}_{F_7}$ is $\mathcal{L}_{F_7}$ itself. Thus Figure 1 describes the world of binary clutters.

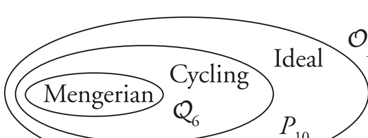

Figure 1. The world of binary clutters

Let $\mathcal{H}$ be a clutter and $i \in E(\mathcal{H})$. The *contraction* $\mathcal{H} / i$ and *deletion* $\mathcal{H} \setminus i$ are clutters with ground set $E(\mathcal{H}) - \{i\}$ where: $\mathcal{H} / i$ is the set of inclusion-wise minimal members of $\{S - \{i\} : S \in \mathcal{H}\}$ and; $\mathcal{H} \setminus i := \{S : i \notin S \in \mathcal{H}\}$. Contractions and deletions can be performed sequentially, and the result does not depend on the order. A clutter obtained from $\mathcal{H}$ by a sequence of deletions and a sequence of contractions is called a *minor* of $\mathcal{H}$. It can be readily checked that if a clutter is Mengerian (resp. cycling or ideal) then so are all its minors. Thus we can attempt to characterize these clutters by describing the smallest (minor minimal) clutters not in these classes. This was done by Seymour [17] for the Mengerian property:

Theorem 2.1. *A binary clutter is Mengerian if and only it has no $\mathcal{Q}_6$ minor.*

A short proof of this result can be found in [7] (see also [16]). Such a characterization remains elusive for the class of binary ideal and cycling clutters. However, the following excluded minor characterizations are predicted.

Idealness conjecture:
A binary clutter is ideal if and only if it has none of the following minors: $\mathcal{L}_{F_7}$, $\mathcal{O}_{K_5}$, $b(\mathcal{O}_{K_5})$.

Cycling conjecture:
A binary clutter is cycling if and only if it has none of the following minors: $\mathcal{L}_{F_7}$, $\mathcal{O}_{K_5}$, $b(\mathcal{O}_{K_5})$, $\mathcal{P}_{10}$.

The conjecture on ideal clutters was proposed by Seymour ([17] p. 200, [18] (9.2), (11.2)). The definition of cycling is due to Seymour [18] who was the first to suggest an excluded minor characterization for this class of clutters.

3. Clutters of odd Circuits

A *signed graph* is a pair $(G, \bullet)$ where G is an undirected graph and $\bullet \subseteq E(G)$. We think of the edges in $\bullet$ as having odd length while the other edges have even length. A set of edges U is *odd* if $|U \cap \bullet|$ is odd and *even* otherwise. An edge e is *odd* if $e \in \bullet$ and *even* otherwise. The set of all odd circuits of $(G, \bullet)$ forms a clutter, denoted $C(G, \bullet)$, with ground set $E(G)$. This clutter is binary. To see this, consider any three odd circuits C_1, C_2, C_3. Since C_1, C_2, C_3 are odd, so is $C_1 \Delta C_2 \Delta C_3$. Hence, the Eulerian subgraph $C_1 \Delta C_2 \Delta C_3$ can be decomposed into circuits which are not all even.

A set $\bullet' \subseteq E(G)$ is a *signature* of $(G, \bullet)$ if $C(G, \bullet) = C(G, \bullet')$. Consider a signed graph $(G, \bullet)$ and let $\delta(U)$ be a cut of G. Since $\delta(U)$ intersects every cycle with even parity, $\bullet \Delta \delta(U)$ is a signature of $(G, \bullet)$. We call the operation which consists of replacing $\bullet$ by $\bullet \Delta \delta(U)$ a *signature-exchange*. In a signed graph $(G, \bullet)$, *deleting* an edge means removing it from the graph. *Contracting* an edge e means first (if necessary) doing a signature-exchange so that e is even (i.e. not in the signature) and then removing the edge and identifying its ends. A minor of a signed graph, is any signed graph obtained by a sequence of deletions, contractions, and signature exchanges. Note that

$$C(G, \bullet) / e = C((G, \bullet)/ e) \text{ and}$$
$$C(G, \bullet) \setminus e = C((G, \bullet)\setminus e).$$

Thus there is a one-to-one correspondence between minor operations on a signed graph and minor operations on the corresponding clutter of odd circuits.

For $n \geq 3$, an *odd-K_n*, denoted $\tilde{K}_n$, is the signed graph $(K_n, E(K_n))$. A signed graph $(G, \bullet)$ is said to be *strongly bipartite* if the clutter $C(G, \bullet)$ is Mengerian. Observe that $\mathcal{Q}_6 = C(\tilde{K}_4)$. Thus Theorem 2.1 can be specialized as follows,

Corollary 3.1. *A signed graph $(G, \bullet)$ is strongly bipartite if and only if it has no $\tilde{K}_4$ minor.*

A signed graph $(G, \bullet)$ is said to be *weakly bipartite* if the clutter $C(G, \bullet)$ is ideal. Observe that $\mathcal{O}_{K_5} = C(\tilde{K}_5)$. It can be readily checked that $b(\mathcal{O}_{K_5})$ and $\mathcal{L}_{F_7}$ are not clutters of odd circuits. Thus the following theorem of Guenin [5] is a special case of the *Idealness conjecture*,

Theorem 3.2. *A signed graph is weakly bipartite if and only if it has no $\tilde{K}_5$ minor.*

For a short proof of this result see Schrijver [15]. We will call a set of edges which intersect all odd circuits of a signed graph $C(G, \bullet)$ a *cover*. The elements of $b(C(G, \bullet))$ are the set of inclusion-wise minimal covers. It is easy to check that all minimal covers of $C(G, \bullet)$ are of the form $\bullet \Delta \delta(U)$ where $\delta(U)$ is a cut. Suppose for all vertices v, $w(\delta(\{v\}))$ is even. It implies that $w(\delta(U))$ is even for all cuts $\delta(U)$. Now consider, $D, D' \in b(C(G, \bullet))$. Then $D = \bullet \Delta \delta(U)$ and $D' = \bullet \Delta \delta(U')$ and $w(D \Delta D') = w(\delta(U \Delta U'))$ which is even. Thus the weights w are Eulerian, as defined in Section 2. Moreover, it can be readily checked that w are Eulerian exactly when $w(\delta(\{v\}))$ is even for all vertices v. A signed graph$(G, \bullet)$ is said to be *evenly bipartite* if the clutter $\mathcal{C}(G, \bullet)$ is cycling. Since $\mathcal{P}_{10}$, $b(\mathcal{O}_{K_5})$, and $\mathcal{L}_{F_7}$ are not clutters of odd circuits, the following theorem of Geelen and Guenin [2] is a special case of the *Cycling conjecture* and a strengthening of Theorem 3.2.

Theorem 3.3. *A signed graph is evenly bipartite if and only if it has no $\tilde{K}_5$ minor.*

Hence, a signed graph is evenly bipartite if and only if it is weakly bipartite, i.e. the Mengerian and ideal properties are identical for the clutters of odd circuits.

4. Multicommodity Flows

The presentation in this section draws heavily on the paper of Geelen and Guenin [2]. See also Gerards [3] and Schrijver [16]. We begin by defining the multicommodity flow problem. We are given an (undirected) graph G, a subset $\bullet \subseteq E(G)$, and a function $w \in \mathbb{Z}_+^{E(\mathcal{H})}$. An edge $d \in \bullet$ is called a *demand edge*, and w_d is the *demand* on d. For $e \in E - \bullet$, we call w_e the *capacity* of e. Let $\mathcal{C}_1$ be the set of all circuits C of G such that $|C \cap \bullet|=1$. Thus, if $C \in \mathcal{C}_1$ then there exists a demand edge $d \in \bullet$ such that $C - \{d\}$ is a path connecting the ends of d. We say that $y \in \Re_+^{\mathcal{C}_1}$ is a $(G, \bullet, w)$–*flow* if:

(1) For each $d \in \bullet$, $\bullet\ (y_C : d \in C \in \mathcal{C}_1) = w_d$, and
(2) For each $e \in E - \bullet$, $\bullet\ (y_C : e \in C \in \mathcal{C}_1)$ ″ w_e.

The first condition asks that the demands are satisfied, and the second condition asks that the capacities are not exceeded. A flow y is an *integer flow* if $y \in \mathbb{Z}^{\mathcal{C}_1}$, and y is a *half–integer flow* if $2y \in \mathbb{Z}^{\mathcal{C}_1}$. A natural condition for the existence of a flow is that, the demand across a cut should not exceed its capacity. That is:

Remark 4.1 (Cut–condition). For all $U \subseteq V$, $w(\delta(U) - \bullet) \geq w(\delta(U) \cap \bullet)$.

This condition is not sufficient for the existence of a flow as the following example illustrates. Consider K_5 and $\delta(U)$ be a cut with two vertices and three vertices on each of the shores. Let $\bullet = E(K_5) - \delta(U)$. Note $\tilde{K}_5$ can be obtained by signature-exchange from$(K_5, \bullet)$. Consider $(K_5, \bullet)$ and suppose and that all demands and capacities are equal to one, i.e. $w(e) = 1$ for all $e \in E(K_5)$. It can be readily checked that the cut-condition holds. However, we claim that no flow exists. Every path included in $E(K_5) - \bullet$ joining two endpoints of a demand edge contains at least two edges. The total demand is $|\bullet| = 4$. Thus the total capacity required for a flow to exists is at least $4 \times 2 = 8$. However, $|E(K_5) - \bullet| = 6$, a contradiction. In the next statement we consider the linear programs (P) and (D) of Section 2 for the clutters $\mathcal{H} = \mathcal{C}(G, \bullet)$.

Proposition 4.2. *Consider a signed graph $(G, \bullet)$ and $w \in \mathbb{Z}_+^{E(\mathcal{H})}$ such that the cut-condition holds. If (P) has an optimum integer solution then there exists a $(G, \bullet, w)$-flow. If in addition (D) has a (1/2) integer solution then there exists a (1/2) integer flow.*

Proof. Suppose that the cut–condition is satisfied. It follows that, for all $U \subseteq V(G)$,

$$w(\bullet\ \Delta\ \delta(U)) \geq w(\bullet).$$

Since all minimal covers are of the form $\bullet\ \Delta\ \delta(U)$, it follows that $\bullet$ is a minimum cover. Hence, the characteristic vector $\hat{x}$ of $\bullet$ is an optimum integer solution to (P). Since (P) has an optimum solution which is integer, $\hat{x}$ is an optimum solution to (P). Let $y \in \mathbb{Z}_+^{\mathcal{C}(G,\bullet)}$ be an optimum solution to (D). Now, by the complementary slackness conditions, we see that

(i) for $C \in \mathcal{C}(G, \bullet)$, if $y_C > 0$ then $|C \cap \bullet| = 1$, and
(ii) for each $d \in \bullet$ (i.e. $\hat{x}_d > 0$), $\bullet\ (y_C : e \in C \in \mathcal{C}(G, \bullet)) = w_d$.

Therefore, the restriction of y to $\mathcal{C}_1$ gives a $(G, \bullet, c)$–flow (which is integer or 1/2-integer if y is).

Consider a signed graph $(G, \bullet)$ and supplies/demands $w \in \mathbb{Z}_+^{E(\mathcal{H})}$. Suppose $(G, \bullet)$ has no $\tilde{K}_4$ minor. Then Corollary 3.1 implies that $(G, \bullet)$ is strongly bipartite. It follows that (P) and (D) have optimum integer solutions for the clutters of odd circuits of $(G, \bullet)$. Hence, by Proposition 4.2 there exists an integer $(G, \bullet, w)$-flow. Similarly, we obtain the following corollary of Proposition 4.2 and Theorem 3.3,

Corollary 4.3. *Let $(G, \bullet)$ be a signed graph with no $\tilde{K}_5$ minor. Let $w \in \mathbb{Z}_+^{E(\mathcal{H})}$ be Eulerian weights and suppose the cut–condition holds. Then there exists an integer $(G, \bullet, w)$-flow.*

It is straightforward to verify that each of the signed graphs given in the next corollary do not contain a $\tilde{K}_5$ minor. Hence, the following results are an immediate consequence of Corollary 4.3.

Corollary 4.4. *Let $(G, \bullet)$ be a signed graph with Eulerian weights $w \in \mathbb{Z}_+^{E(\mathcal{H})}$ which satisfy the cut–condition. Then there exists an integer $(G, \bullet, w)$-flow in the following cases:*

(i) *if* $|\bullet| = 2$,
(ii) *if G is planar*,
(iii) *if $\bullet\ \Delta\ \delta(U)$ is a circuit of length 5 for some cut $\delta(U)$*,
(iv) *if $(G, \bullet)$ has an even–face embedding on the Klein bottle.*

Case (i) is known as the two commodity flow theorem, see Hu [9] and also Rothschild and Whinston [14]. Case (ii) was show by Seymour [19]. Case (iii) was proved by Lomonosov [13] for the case where $\delta(U) = \emptyset$ and Gerards (personal communication) observed that these signed graphs have no $\tilde{K}_5$ minor. Case (iv) was shown by Gerards and Sebő [4]. The Klein bottle is obtained from the 2-sphere by adding two cross-caps. An even-face embedding is an embedding where all facial circuits are even. This result is a generalization of the case of the projective plane [8].

5. Extentions and Related Problems

We first wish to present two different generalizations of Theorem 3.2 which are both special cases of the *Idealness conjecture*. For a clutter $\mathcal{H}$ and $v \notin E(\mathcal{H})$, the clutter $\mathcal{H}^+$ has ground set $E(\mathcal{H}) \cup \{v\}$ and $\mathcal{H}^+ = \{C \cup \{v\} : C \in \mathcal{H}\}$. Cornuéjols and Guenin [1] showed,

Theorem 5.1. *A binary clutter is ideal if it has none of the following minors: $\mathcal{L}_{F_7}$, $\mathcal{O}_{K_5}$, $b(\mathcal{O}_{K_5})$, $\mathcal{Q}_6^+$, $b(\mathcal{Q}_6)^+$.*

It is easy to check that neither $\mathcal{Q}_6{}^+$ nor $b(\mathcal{Q}_6)^+$ is a clutter of odd circuits. Hence, the previous theorem implies Theorem 3.2. We call a subset of edges of $(G,\bullet)$ an *odd st-walk* if it is an odd *st*-path; or it is the union of an even *st*-path P and an odd circuit C, where P and C share at most one vertex. It is easy to verify that clutters of odd *st*-walks are closed under taking minors. The family of odd *st*-walks form a binary clutter. Guenin [6] showed,

Theorem 5.2. *A clutter of odd st-walks is ideal if and only if it has no* $\mathcal{L}_{F_7}$ *and no* $\mathcal{O}_{K_5}$ *minor.*

If $s = t$ there exist no odd *st*-paths in $(G,\bullet)$. Hence, in that case, the clutter of odd *st*-walks is the clutter of odd circuits. Since the clutter $\mathcal{L}_{F_7}$ is not a clutter of odd circuits, the previous theorem also implies Theorem 3.2.

The 4-colour theorem [10] states that we can 4-colour the vertices of any planar graph (i.e all vertices of G can be coloured one of 4 colours such that adjacent vertices are assigned different colours). We say that G contains K_5 as a *minor* if K_5 can be obtained from G by first contracting a subset of edges and then deleting loops. We say that G contains K_5 as an *odd minor* if K_5 can be obtained from G by contracting all the edges of some cut and then deleting loops. Wagner [20] showed that the 4-colour theorem implies that we can 4-colour the vertices of graphs with no K_5-minors. Gerards (personal communication) conjectured the following extension,

Conjecture 5.3. *We can 4-colour the vertices of graphs with no* K_5 *as odd minor.*

We claim that this is a special case of the *Cycling conjecture*. Consider a graph G which does not contain K_5 as an odd minor. Then it can be easily checked that $(G,E(G))$ has no $\tilde{K}_5$ minor, and hence $b(\mathcal{C}(G,\bullet))$ has no $b(\mathcal{O}_{K_5})$ minor. If the conjecture holds this implies that $b(\mathcal{C}(G,\bullet))$ is cycling. Let w be the vector of all ones. Let C_1,C_2 be odd circuits. Then $w(C_1 \Delta C_2) = |C_1 \Delta C_2|$ is even. It follows that w are Eulerian (according to the definition of Section 2). Since every odd circuit of G has length at least three, the value of the optimum integer solution for (P), with clutter $b(\mathcal{C}(G,\bullet))$, is at least three. Thus there exists an optimum integer solution for (D) of value at least three. An integer solution of (D) corresponds to a family of disjoint covers $B_1,\dots,B_k$ where $k \geq 3$. For $i = 1,2$ let H_i denote the bipartite graph $G \setminus B_i$ and let V_i, V_i' be the corresponding partition of the vertices of H_i. Let us label each vertex v of G with the elements of the $Z_2 \times Z_2$ group as follows: if $v \in V_1 \cap V_2$ then v is labeled 00, if $v \in V_1' \cap V_2$ then v is labeled 10, if $v \in V_1 \cap V_2'$ then v is labeled 01, if $v \in V_1' \cap V_2'$ then v is labeled 11. We claim that the colours given by the elements of $Z_2 \times Z_2$ are a 4-colouring of the vertices of G. For otherwise we would have an edge uv where both u, v are in say $V_1 \cap V_2$. But since H_i is bipartite, $uv \in B_i$ for $i = 1,2$, a contradiction as $B_1 \cap B_2 = \emptyset$.

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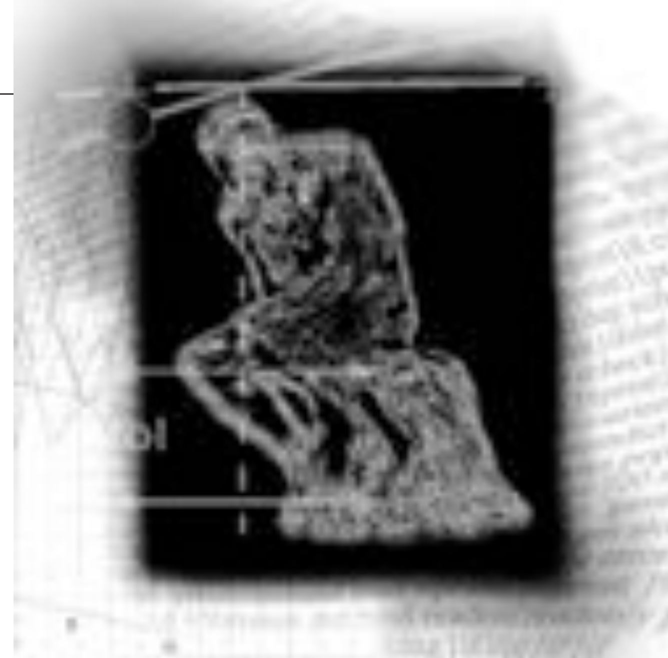
mindsharpener



We invite OPTIMA readers to submit solutions to the problems to Robert Bosch (bobb@cs.oberlin.edu). The most attractive solutions will be presented in a forthcoming issue.

Monochromatic Squares

Robert A. Bosch

November 6, 2003

Fill the squares of an $n \times n$ grid with black and white stones, and count the number of monochromatic squares that are formed. Note that the arrangement displayed in Figure 1 gives rise to just one monochromatic square.

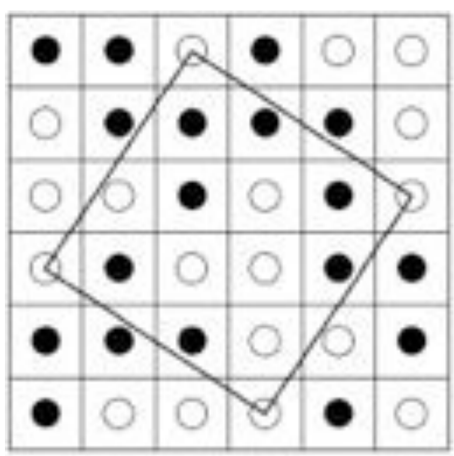


Figure 1

Interested readers may enjoy trying to solve instances of the Monochromatic Squares Problem: *Arrange black and white stones in an n x n grid in such a way that the number of monochromatic squares is minimized.*

I found this problem on Al Zimmermann's "Squares Programming Contest" webpage (`http://members.aol.com/Bitzenbeitz/Contests/Squares/`). To win the contest, you'll need to solve the Monochromatic Squares Problem for all values of n from 7 to 31. The grand prize is $500 and the deadline is noon GMT on January 18, 2004. See Zimmermann's website for details!

Nontransitive Dice Revisited

The first problem in the previous installment of *Mindsharpener* involved devising an IP or CP formulation that could be used to find a set of nontransitive dice. The second problem was to use the formulation to find a set of three dice $\{D_1, D_2, D_3\}$ with the following properties: (i) each face has a number between 1 and 18 on it, (ii) each number in this range appears on exactly one face, and (iii) $\text{Prob}(D_1 \succ D_3)$ ″ $\text{Prob}(D_2 \succ D_1)$ ″ $\text{Prob}(D_3 \succ D_2)$. The objective was to maximize $\text{Prob}(D_1 \succ D_3)$.

Alex Meeraus of the GAMS Development Corporation submitted a very nice IP formulation based on a formulation devised a number of years ago by his colleague Paul van der Eijk. To my knowledge, van der Eijk was the first to use integer programming to find sets of nontransitive dice. His model is a part of the GAMS Model Library (`http://www.gams.com/modlib/libhtml/dice.htm`).

The Meeraus/van der Eijk model uses three sets of variables. (I have taken the liberty of rewriting their model slightly and using my own notation.) Let x_{fd} equal the number showing on face f of die d. Let $y_{fdf'}$ equal 1 if face f of die d is greater than face f' of the die that die d is supposed to beat; let $y_{fdf'}$ equal zero if this is not the case. (Recall that we'd like die 1 to beat die 3, die 2 to beat die 1, and die 3 to beat die 2.) And let z_{kfd} equal 1 if the number k is assigned to face f of die d, and 0 if not. The Meeraus/van der Eijk model is

$$\text{maximize} \quad \sum_f \sum_{f'} y_{f1f'} \tag{1}$$

$$\text{subject to} \quad \sum_f \sum_{f'} y_{f2f'} \geq \sum_f \sum_{f'} y_{f1f'} \tag{2}$$

$$\sum_f \sum_{f'} y_{f3f'} \geq \sum_f \sum_{f'} y_{f2f'} \tag{3}$$

$$x_{f1} + 18(1 - y_{f1f'}) \geq x_{f'3} + 1 \qquad \forall f \, \forall f' \tag{4}$$

$$x_{f'3} + 17 y_{f1f'} \geq x_{f1} \qquad \forall f \, \forall f' \tag{5}$$

$$x_{f2} + 18(1 - y_{f2f'}) \geq x_{f'1} + 1 \qquad \forall f \, \forall f' \tag{6}$$

$$x_{f'1} + 17 y_{f2f'} \geq x_{f2} \qquad \forall f \, \forall f' \tag{7}$$

$$x_{f3} + 18(1 - y_{f3f'}) \geq x_{f'2} + 1 \qquad \forall f \, \forall f' \tag{8}$$

$$x_{f'2} + 17 y_{f3f'} \geq x_{f3} \qquad \forall f \, \forall f' \tag{9}$$

$$x_{fd} = \sum_k k z_{kfd} \qquad \forall f \, \forall d \tag{10}$$

$$\sum_k z_{kfd} = 1 \qquad \forall f \, \forall d \tag{11}$$

$$\sum_f \sum_d z_{kfd} = 1 \qquad \forall k \tag{12}$$

$$x_{fd} \geq x_{d,f-1} + 1 \qquad \forall f \, \forall d > 1 \tag{13}$$

$$\text{all } x_{fd}\text{'s intergral; all } y_{fdf'}\text{'s and } z_{kfd}\text{'s binary.} \tag{14}$$

The objective (1) is to maximize the number of ways in which die 1 beats die 3. By maximizing this, we are maximizing Prob ($D_1 \succ D_3$). Constraint (2) ensures that the number of ways in which die 2 beats die 1 is at least as big as the number of ways in which die 1 beats die 3. In other words, constraint (2) makes sure that Prob($D_2 \succ D_1$) ≥ Prob($D_1 \succ D_3$). Constraint (3) is similar, guaranteeing that Prob($D_3 \succ D_2$) ≥ Prob ($D_2 \succ D_1$). Together, constraints (2) and (3) ensure that the set of dice is nontransitive.

Constraints (4) and (5) "define" the $y_{f1f'}$'s. Note that when $y_{f1f'} = 1$, $x_{f1} > x_{f'3}$ and that when $y_{f1f'} = 0$, $x_{f'3} \geq x_{f1}$. Similarly, constraints (6) and (7) define the $y_{f2f'}$'s and constraints (8) and (9) define the $y_{f3f'}$'s.

Constraint (10) establishes the necessary "links" between the x_{fd}'s and the z_{kfd}'s. Constraint (11) makes sure that each face of each die receives exactly one number, and constraint (12) guarantees that each number appears exactly once. Constraint (13) is used to reduce the size of the search space.

Alex Meeraus's solution is displayed in Figure 2. Note that Prob($D_1 \succ D_3$) = Prob($D_2 \succ D_1$) = Prob($D_3 \succ D_2$) = 7/12. Meeraus reported that it took CPLEX about 20 seconds to obtain the solution.

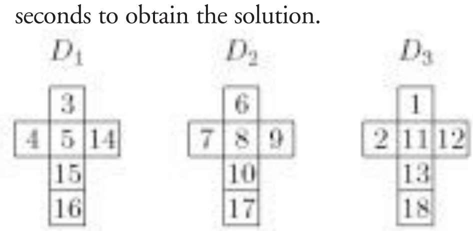


Figure 2

Operations Research 2005 (OR 2005)

International Conference on Operations Research

September 7 - 9, 2005
University of Bremen,
Bremen, Germany

Contact:

Prof. Dr. H.-D. Haasis
haasis@uni-bremen.de

Prof. Dr. H. Kopfer
kopfer@uni-bremen.de

In Memoriam

Jos Sturm, recently elected as an at-large member of the MPS Council, died on December 6, 2003. He suffered a cerebral hemorrhage on October 8, 2003, from which he never recovered. Jos was 32 years old. All our thoughts and sympathy go to his wife Changqing, their daughter Stefanie, and to his family. We deeply regret the loss of a colleague and dear friend. Jos' dedication to his work, his endless enthusiasm, his kindness and readiness to help will be very much missed. Jos made important contributions to the field of Optimization. He was particularly known for SeDuMi, an algorithm he developed for semidefinite optimization. Jos' life will be remembered with an article in the next issue of Optima.

mps
Mathematical
Programming
Society

Prizes awarded by the Mathematical Programming Society and Society for Industrial and Applied Mathematics --

"Rewards for outstanding work in a field promote its quality as well as bring it deserving publicity."

Mathematical Programming Society awards prizes to promote excellence and to reward achievement in mathematical programming. Most prizes are awarded at the triennial symposium of the society. Some are co-sponsored by other professional societies, including the Society for Industrial and Applied Mathematics and the American Mathematical Society.

2003 Fulkerson Prize Committee
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G. Cornuejols
A. Odlyzko (AMS appointee)

2003 Dantzig Prize Committee
B. Cunningham
L. Wolsey
O. Mangasarian (SIAM member)
R. Fletcher (SIAM member)

2003 Beale-Orchard-Hays Prize Committee
W. Cook
D. Bienstock
N. Gould
J. More

2003 Tucker Prize Committee
R. Burkard
T. McCormick
J. Sturm
L. Trotter

2003 Lagrange Prize in Continuous Optimization Committee
S. J. Wright
C. T. Kelley
C. Lemarechal
M. Todd

2003 Fulkerson Prize Citation

J. F. Geelen, A. M. H. Gerards, A. Kapoor, "The Excluded Minors for GF(4)-Representable Matroids," Journal of Combinatorial Theory B 79 (2000), 247-299.

Matroid representation theory studies the question of when a matroid is representable by the columns of a matrix over some field. The matroids representable over GF(2) and GF(3) were characterized by their excluded minors in the 1950s and the 1970s respectively. Rota then conjectured that the matroids representable over any finite field GF(q) could be characterized in terms of a finite list of excluded minors. For more than twenty five years, progress on Rota's conjecture stalled. The proofs for GF(2) and GF(3) relied on the uniqueness properties of representations over these fields, properties that do not hold for other fields. Thus the result of Geelen, Gerards and Kapoor came as a big surprise. The paper of Geelen, Gerards and Kapoor gives an excluded minor characterization for matroids represented over GF(4) by working around the non-uniqueness of the representation. It has reawakened interest in the area of matroid representation and brought renewed hope of progress towards the solution of Rota's conjecture.

B. Guenin, "A characterization of weakly bipartite graphs," Journal of Combinatorial Theory B 83 (2001), 112-168.

A long-standing area of interest in the field of discrete optimization is finding conditions under which a given polyhedron has integer vertices, so that integer optimization problems can be solved as linear programs. In the case of a particular set covering formulation for the maximum cut problem, a graph is called weakly bipartite if the polyhedron has integer vertices for that graph. Guenin's result gives a precise characterization of the graphs that are weakly bipartite in terms of an excluded minor. This solves the graphical case of a famous conjecture about ideal binary clutters made by Seymour in his 1977 Fulkerson Prize-winning paper. Guenin's proof makes an ingenious use of a deep theorem of Lehman, also itself a Fulkerson Prize winner. Guenin's work has motivated several remarkable subsequent papers.

S. Iwata, L. Fleischer, and S. Fujishige, "A combinatorial, strongly polynomial-time algorithm for minimizing submodular functions," Journal of the ACM 48 (2001), 761-777, and **A. Schrijver**, "A combinatorial algorithm minimizing submodular functions in strongly polynomial time," Journal of Combinatorial Theory B 80 (2000), 346-355.

Submodular functions provide a discrete analog of convex functions, and submodular function minimization arises in such diverse areas as dynamic and submodular flows, facility location problems, multiterminal source coding, and graph connectivity problems. The first polynomial-time algorithm for submodular function minimization was given by Grötschel, Lovász, and Schrijver in 1981; however, the algorithm relies on the ellipsoid method, requires advance knowledge of bounds on the function values, and is not combinatorial. In 1999, the papers of Iwata, Fleischer, and Fujishige, and of Schrijver independently gave combinatorial, strongly polynomial-time algorithms for this fundamental problem. These results are a significant step in the history of combinatorial, strongly polynomial-time algorithms for discrete optimization problems, and can be compared with the Edmonds-Karp algorithm for the maximum flow problem and Tardos's algorithm for the minimum-cost flow problem.

2003 Dantzig Prize Citation

Jong-Shi Pang is a world leader in the field of equilibrium programming, variational inequalities and complementarity problems. He has made major contributions to the basic theory and algorithms, and to the analysis, solution, and unification of many application problems in these areas. His many books include the classic, "The Linear Complementarity Problem," written jointly with R.W. Cottle and R.E. Stone, which won the 1994 INFORMS Lanchester Prize. Pang's numerous papers have helped shape the careers of many outstanding young researchers world wide and have attracted many of them to work in the important field of mathematical programming. This, coupled with the breadth and profoundness of his work, makes Pang eminently deserving of the Dantzig Prize.

Alexander Schrijver has made deep and fundamental research contributions to discrete optimization, including the applications of the ellipsoid method in combinatorial optimization, disjoint paths on surfaces, matrix cones and their applications, polyhedral and cutting plane theory, and submodular functions. His landmark book, "Theory of Linear and Integer Programming," and his three-volume work, "Combinatorial Optimization: Polyhedra and Efficiency," constitute definitive accounts of the history and present state of discrete optimization, and will influence researchers for decades to come. Characterized by insights that are both broad and deep, and by a continual pursuit of simplification and unity, Schrijver's work is scholarship at its best.

2003 Beale-Orchard-Hays Prize Citation

Elizabeth D. Dolan, Robert Fourer, Jorge J. Moré, Todd S. Munson, "Optimization on the NEOS Server," SIAM News 35 (6), 2002.

The NEOS Server has had a tremendous impact in the field of optimization, extending the reach of a wide selection of fundamental algorithms to a growing number of new applications areas. The influence of NEOS is such that in many applied fields the NEOS Server is synonymous with optimization.

An on-going software project like NEOS involves the efforts of many people and we hope the numerous contributors to NEOS will take pride in sharing this award with the prize winners.

2003 Tucker Prize Citation

At the XVIII Mathematical Programming Symposium in Copenhagen the Tucker Prize for an outstanding paper authored by a student has been awarded to **Tim Roughgarden**, Cornell University, for his thesis "Selfish Routing".

The other two Tucker Prize finalists chosen by this year's Tucker Prize Committee consisting of Rainer Burkard (Chair), Thomas McCormick, Jos Sturm and Leslie Trotter are **Pablo Parrilo** and **Jiming Peng**. **Tim Roughgarden**, who obtained his BS and MS degrees from Stanford University completed his Ph.D. thesis in May 2002 under the guidance of Eva Tardos. Currently, Dr. Roughgarden continues his work at Cornell University as a postdoc. His thesis considers the classic problem of designing traffic networks that lead to good global routings even when the users are making local, suboptimal decisions. This touches on several disciplines such as game theory, network flows, complexity analysis, approximation algorithms, and economics. Roughgarden analyzes the "price of anarchy," i.e., the gap between a socially-optimal global solution and the solution resulting from selfish users, and finds a variety of tight results on what is achievable with reasonable amounts of computation. He further broadens this out to models of other situations with selfish users.

Pablo Parrilo obtained his first degrees in Electronic Engineering from the University of Buenos Aires. He obtained a Ph.D. in Control and Dynamical Systems from California Institute of Technology in June 2000 under the guidance of John Doyle. Currently, Dr. Parrilo is Assistant Professor of Analysis and Control Systems at ETH Z\"urich. Dr. Parrilo was nominated as Tucker Prize finalist for his paper, "Semidefinite programming relaxations for semialgebraic methods." This work establishes a bridge between convex optimization and real algebraic geometry, which opens up a new and promising research area. The main idea is to explore conditions under which a function can be proved to be non-negative by showing that it is a sum of squares. Parrilo shows applications of this in diverse areas such as non-convex quadratic programming, matrix copositivity, linear algebra, and control theory.

Jiming Peng was born in Hunan Province, China. He obtained his first degrees in China. In 1997 Peng moved to Delft University of Technology where he received his Ph.D. for his prize winning thesis entitled, "New Design and Analysis of Interior-Point Methods". His thesis was guided by C. Roos and T. Terlaky. Peng's work goes a long way to closing the gap between the superior theoretical performance of short-step interior-point methods, and the superior practical performance of long-step methods. Peng does this by inventing a new class of barrier functions called "self-regular" which allow long-step methods to be implemented with theoretical time bounds very close to short-step methods. He applies this to linear, complementarity, second-order cone, and semi-definite problems. Currently, Dr. Peng joined the Department of Computing and Software, McMaster University, as an Assistant Professor.

2003 Lagrange Prize in Continuous Optimization Citation

Adrian Lewis, "Nonsmooth Analysis of Eigenvalues," Mathematical Programming 84 (1999), pp. 1-24.

Using tools from convex and nonsmooth analysis, this paper establishes an elegant and compact chain rule to find the subdifferential of virtually any function of the spectrum of a symmetric matrix. It shows that a somewhat unusual view of symmetric matrices (as being largely functions of their eigenvalues) is the key to developing conceptual and technical tools for optimization over the symmetric matrices. The paper crowns a series of papers by Lewis on the analysis of spectral functions. Like the other papers in this series, it does a superb job of connecting optimization to important currents in modern mathematics and in conveying the spirit of the underlying mathematics to its optimization audience. It exposes the highly technical subject matter forcefully and uncompromisingly, yet is written in a remarkably lucid and engaging style.

CALL FOR NOMINATIONS

Optimization Prize for Young Researchers

PRINCIPAL GUIDELINE: The Optimization Prize for Young Researchers, established in 1998 and administered by the Optimization Society (OS) within the Institute for Operations Research and Management Science (INFORMS), is awarded annually at the INFORMS Fall National Meeting to one (or more) young researchers for the most outstanding paper in optimization that is submitted to or published in a refereed professional journal. The prize serves as an esteemed recognition of promising colleagues who are at the beginning of their academic or industrial career.

DESCRIPTION OF THE AWARD: The optimization award includes a cash amount of US$1,000 and a citation certificate. The award winners will be invited to give a fifteen minute presentation of the winning paper at the Optimization Section Business Meeting held during the INFORMS Fall National Meeting in the year the award is made. It is expected that the winners will be responsible for the travel expenses to present the paper at the INFORMS meeting.

ELIGIBILITY: The authors and paper must satisfy the following three conditions to be eligible for the prize:

(a) The paper must either be published in a refereed professional journal no more than three years before the closing date of nomination, or be submitted to and received by a refereed professional journal no more than three years before the closing date of nomination.

(b) All authors must have been awarded their terminal degree within five years of the closing date of nomination.

(c) The topic of the paper must belong to the field of optimization in its broadest sense.

NOMINATION: A letter of nomination should be sent (preferably by email) on or before this year's closing date of June 1, 2004, to:

Prof. Tamás Terlaky
Canada Research Chair in Optimization
Department of Computing and Software
McMaster University
1280 Main Street West Hamilton
Ontario, Canada, L8S 4K1
Phone: +1-905 525-9140 ext. 27780,
FAX: +1-905 524-0340
Email: terlaky@mcmaster.ca

PAST AWARDEES. The past winners of the Optimization Prize for Young Researchers are:

Year	Prize Winner
1999	Francois Oustry
2000	Kevin Wayne
2001	Kamal Jain
2002	Sam Burer
2003	Tim Roughgarden

ISMP 2003 - experiences and reflections

The 18 International Symposium on Mathematical Programming was held in Copenhagen in August 2003. The organization committee consisted of 5 persons with me as chair. In the following, I pass on some of the experiences gained - hopefully, this will be of value for future organizers of ISMP.

Number of participants and talks.

Key numbers in connection with large arrangements as ISMP are: the number of participants, the number of invited and contributed talks, and the amount of sponsorship funding attracted.

The number of participants is interesting in two aspects: the total number shows the activity of MPS as a society in general, and the number of participants singled out on MPS and non-MPS members, on early registrations and normal registrations, and on students, is important from an economical perspective. The final numbers for ISMP are indicated in the following table.

MPS Member BF April 30:	196
MPS Member AF April 30:	66
MPS Member, Free:	15
Non MPS members BF April 30:	233
Non MPS members AF April 30:	132
Non MPS members, Free:	61
Student BF April 30:	125
Student AF April 30:	48
Student, Free:	61
Exhibitors:	7
Special fee (Danish OR-Society):	2
Sponsor, Free	8
Total:	954

In the first budgets for ISMP we estimated the number of participants to be between 1000 and 1100, however, September 11, 2001 happened in between, and in that perspective, the number of participants was seen from the organizers point of view as satisfactory.

The number of invited talks was 7, among which were 5 plenaries and 12 semi-plenaries. The scientific papers accompanying the talks were all delivered in due time that an issue of Mathematical Programming containing these were available as conference material - the organizers take the opportunity again to thank the authors for their effort and Springer-Verlag for sponsoring the issue.

The number of contributed talks was appr. 730, the appr. indicating that after all a small number of participants did not show. However, due to an organizational coupling between registration of payments and inclusion of abstract in the abstract booklet the organizers managed to keep the number of no-shows to a minimum.

Regarding sponsorship grants, the total amount was 285.000 DKK. These contributions came from companies as well as private foundations and were mainly used to support participation of young researchers and researchers from third world countries. In the table with participant numbers, the "free" participants correspond to participants who had their fees waived. In addition, appr. 25 participants received a grant each of 2000 DKK for partial covering of travel expenses.

The grants were given based on an application procedure with a deadline in March, 2003. The applications - a short application with a list of 5 publications, and for students, a recommendation from the supervisor - were processed by the organization committee. This resulted in a short turn-around time. We received substantially more applications than we were able to grant and some of the sponsorships came in rather late. Therefore, we kept a short waiting list for applicants.

Experiences from the organizational task.

Initiated by the MPS chair Bob Bixby, I had close contact with the MPS executive committee through monthly telephone meetings in the last 9 months before MPS. This was a great help - in that way the organizers were able to drawn upon their experiences and take into account special wishes regarding the organization of e.g. the opening ceremony. Also, the budget and registration fees were discussed with the ISMP executives at an early stage.

The local organization committee was kept at a minimum size, which although giving each member a considerable amount of work, in the end resulted in an effective organization with close collaboration.

We hired a conference agency to deal with registration, hotels, and a lot of other details. Also the development and maintenance of the conference web-page was outsourced to the agency. The production of the booklet of abstracts was handled by members of the organizational committee leading to a smooth production process and a booklet, which we are quite proud of.

We decided early that the only way to feed 1000 people in one hour was to supply basic lunch-bags and include these in the conference fee. Thereby, we avoided lines for paying as well as the decision time incurred when you give people a choice regarding their meal. This worked well.

The conference site was located 10 kilometers out of Copenhagen centre, and the participants were to find their way using public transportation, which was paid for in the conference fee. After some adjustments and after we realized that backup transportation in the morning was a must, this worked satisfactorily, although not perfect.

continue on next page →

IPCO X
June 9-11, 2004
Columbia University
New York City, USA

CONFERENCE SCOPE

This meeting, the tenth in the series of IPCO conferences, is a forum for researchers and practitioners working on various aspects of integer programming and combinatorial optimization. The aim is to present recent developments in theory, computation, and applications of integer programming and combinatorial optimization.

Topics include, but are not limited to:
- integer programming
- polyhedral combinatorics
- cutting planes
- branch-and-cut
- lift-and-project
- semidefinite relaxations
- geometry of numbers
- computational complexity
- network flows
- matroids and submodular functions
- 0,1 matrices
- approximation algorithms
- scheduling theory and algorithms

In all these areas, we welcome structural and algorithmic results, revealing computational studies, and novel applications of these techniques to practical problems. The algorithms studied may be sequential or parallel, deterministic or randomized.

During the three days, approximately thirty papers will be presented, in a series of sequential (non-parallel) sessions. Each lecture will be thirty minutes long. The program committee will select the papers to be presented on the basis of extended abstracts to be submitted.

The proceedings of the conference will be published by Springer as a Lecture Notes in Computer Science volume, and will contain full texts of all presented papers. Copies will be provided to all participants at registration time.

PROGRAM COMMITTEE

George Nemhauser, Chair
Egon Balas
Daniel Bienstock
Bob Bixby
William Cook
Gerard Cornuejols
William Cunningham
Bert Gerards
Ravi Kannan
William Pulleyblank
Laurence A. Wolsey

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Phone: 212 854 2942
Fax: 212 854 8103

IPCO X
Summer School
June 7-8, 2004

The IPCO Summer School will take place June 7 and 8, 2004, and will present the following speakers:

Joan Feigenbaum, Yale University
Tim Roughgarden, UC Berkeley
Rakesh Vohra, Northwestern University

The summer school will focus on the interactions between operations research, computer science, and economics.

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continued from page11

Although sufficient capacity were actually available if both the highway buses and the trains were used, we underestimated the conservativeness of humans - once shown a feasible solution, humans tend to stick to that rather than finding alternatives.

Pitfalls, tips and tricks

I learned a number of lessons during the task as organizational chair:

Regarding my own institution, I know exactly who to speak to about any issue relevant to conference organization. It would, however, have been more convenient to have this knowledge during the organizational process rather than as a result of the process. So, if you take on the obligation to arrange a conference of ISMP-size, do not believe that everything is laid out for you even if this is claimed to be the case from your institution.

You need an "odd-job man" in the team - if you do not have him you will end up with the odd jobs (take my word for it).

Be prepared for a number of applications for invitations from people, who do not want to attend the conference, but who do want to be able to enter your country for other reasons.

In conclusion

I enjoyed ISMP 2003 and had a number of good experiences along the organizational road. I came out as a more knowledgeable person on any number of important issues as well as a number of other issues. It was fun, and I hope the participants enjoyed ISMP 2003 to the same extent as I enjoyed organizing the symposium.

Jens Clausen

Inaugural INTERNATIONAL CONFERENCE on CONTINUOUS OPTIMIZATION
ICCOPT I

The inaugural triennial International Conference on Continuous Optimization will take place on the campus of Rensselaer Polytechnic Institute, Troy, New York, August 2-4, 2004; a website for the Conference is available at:
http://www.math.rpi.edu/iccopt/

This is a Mathematical Programming Society conference. It is a sister conference to IPCO, the Integer Programming and Combinatorial Optimization Conference, and is programmed the year after ISMP, the international symposium on mathematical programming.

It is organized in cooperation with the INFORMS Optimization Section, the Society for Industrial and Applied Mathematics (SIAM) and the SIAM Activity Group on Optimization.

The scientific program of ICCOPT will cover all major aspects of continuous optimization: theory, algorithms, applications, and related problems. A partial list of topics includes

- linear, nonlinear, and convex programming
- equilibrium programming
- semidefinite and conic programming
- stochastic programming
- complementarity and variational inequalities
- nonsmooth and variational analysis
- nonconvex and global optimization
- optimization of partial differential systems
- applications in engineering, economics, finance, statistics, game theory, and bioinformatics
- energy modeling and electric power market modeling
- optimization over computing grids
- modeling languages and web-based optimization systems.

The Conference will consist of a mixture of plenary, semiplenary, invited, and contributed talks. It is anticipated that at most four sessions will be scheduled in parallel. Selected papers will appear in a special issue of Mathematical Programming Series B.

A dedicated session will be devoted to papers by young colleagues, to be chosen by a panel of reviewers. See the separate Call for Papers by Young Researchers for details, including guidelines and submission information. Naturally, submission of papers by these researchers to the general conference is also highly encouraged!

PLENARY SPEAKERS

Confirmed plenary and semiplenary speakers include:
Aharon Ben-Tal
Monique Laurent
Sven Leyffer
Olvi Mangasarian
Carsten Scherer
Alexander Shapiro
Shuzhong Zhang

GENERAL CALL FOR SUBMISSIONS

You are cordially invited to attend the conference and to submit a contributed paper for presentation. Due to the limited number of available slots, the Program Committee may have to decline some submissions. Please send one of the Co-Chairs of the Local Organizing Committee (Jong-Shi Pang, pangj@rpi.edu or John Mitchell, mitchj@rpi.edu) a note before March 1, 2004, indicating if you are interested in (a) attending the Conference, and/or (b) contributing a presentation.

REGISTRATION FEES

To be determined at a later date.

PROGRAM COMMITTEE

Jong-Shi Pang, Program chair
Roberto Cominetti
Nick Gould
Florian Jarre
Tim Kelley
Masakazu Kojima
Jie Sun
Andre Tits

SUMMER SCHOOL

The Conference will be preceded by a summer school for graduate students, junior faculty, and other interested participants, which will describe some of the recent exciting developments in continuous optimization. See separate announcement.

IMPORTANT DATES

April 5, 2004
Deadline for papers for consideration in the special session dedicated to young researchers.

April 15, 2004
Deadline for titles and abstracts (tentative).

April 15, 2004
Registration deadline (tentative).

July 31 and August 1, 2004
Summer school.

August 2-4
ICCOPT I.

CONTACT DETAILS

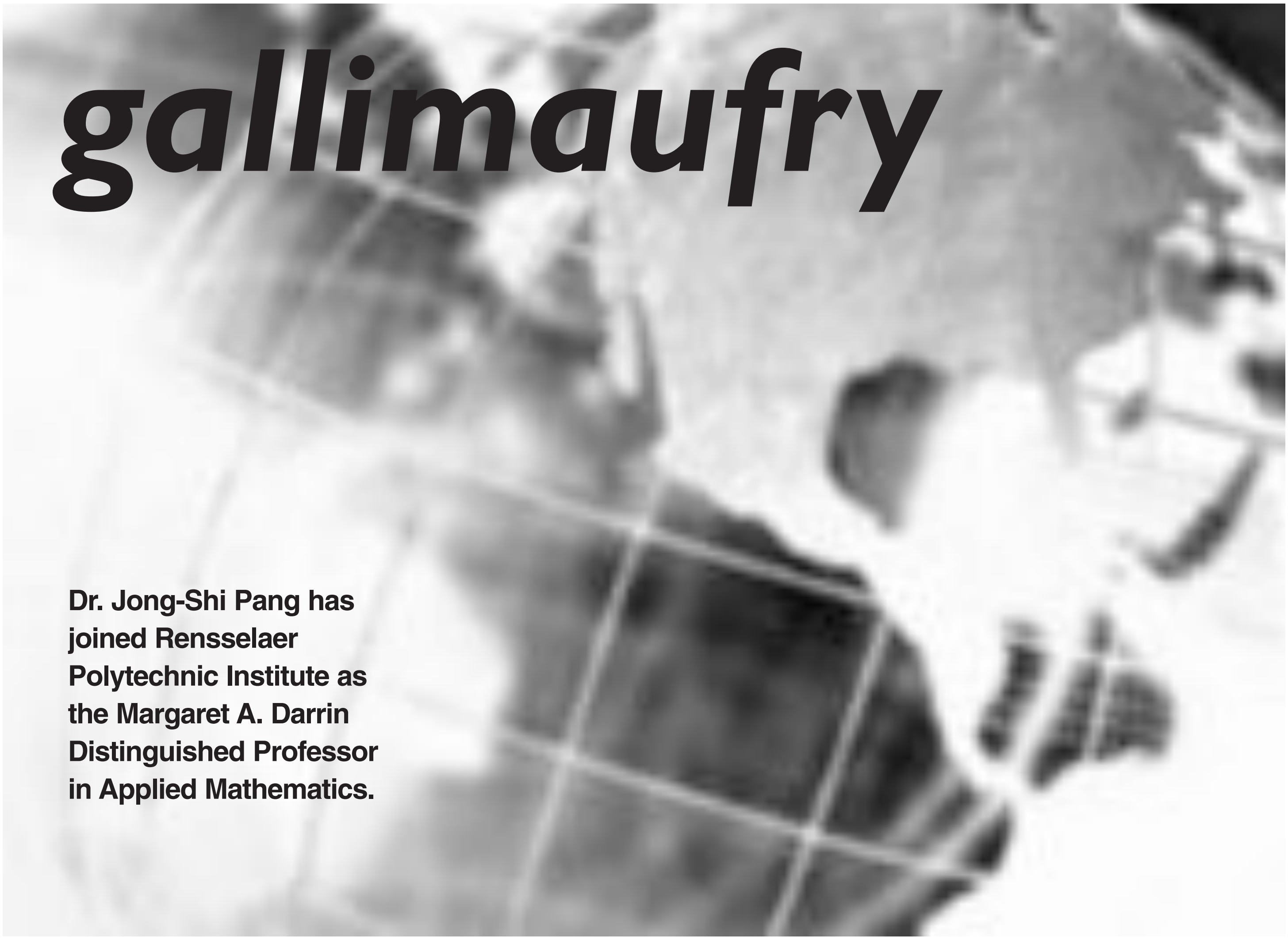
If you are interested in attending the Conference, please drop an email to the local organizers (addresses below).

Details for the Conference will be continuously updated and posted on the website http://www.math.rpi.edu/iccopt/ .

We look forward to hearing from you and to seeing you next summer.

The Local Organizers of ICCOPT I

Jong-Shi Pang pangj@rpi.edu
Co-Chair
John Mitchell mitchj@rpi.edu
Co-Chair (SIAM Representative)
Kristin Bennett bennek@rpi.edu
Member
Joe Ecker eckerj@rpi.edu
Member



gallimaufry

Dr. Jong-Shi Pang has joined Rensselaer Polytechnic Institute as the Margaret A. Darrin Distinguished Professor in Applied Mathematics.

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