MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

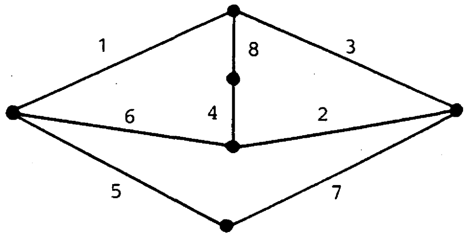
Tagungsbericht 28/1994

Graphentheorie

26. 6. bis 2. 7. 1994

Die Tagung fand erstmals unter der Leitung von C. Thomassen (Lyngby, Dänemark) und B. Toft (Odense, Dänemark) nach vier Jahren wieder statt.

Es nahmen 44 Graphentheoretiker aus 44 Ländern teil. Die neuesten Forschungsergebnisse, über die in 41 Vorträgen berichtet und diskutiert wurde, stammen aus den Gebieten Färbungsprobleme, insbesondere das Vierfarbenproblem, Ramseytheorie, Unendliche Graphen, Zufallsgraphen, Zusammenhangsprobleme, Extremale Graphentheorie, Darstellungen von Graphen und Graphennumerierungen. Die Figur zeigt den kleinsten magischen Graphen (außer K_2), der also eine



Kantennumerierung so zuläßt, daß die Summen an den Knoten alle gleich sind.

In zwei Abendsitzungen wurden offene Probleme vorgestellt und diskutiert.

Gefördert durch DFG Deutsche Forschungsgemeinschaft

Vortragsauszüge

M. AIGNER:

The 4/3-conjecture

Let G be a connected graph, and $\mu(G)$ its mean distance. Winkler's 4/3-conjecture states: $\rho(G) = \min_{u\in V} \mu(G,u)/\mu(G) \leq 3$. The following results were discussed, extending earlier work. (1) $\mu(G) \leq (n-1+k)/2k + k/8(n-1)$, G k-connected, (2) $\rho(G) \leq 1 + 2/3(k-1)\sqrt{k} + 6/(n-2)$, G k-connected, $k \geq 2$ (thus the 4/3-conjecture holds for 3-connected graphs with $n \geq 43$ vertices), (3) $\lim_{n\to\infty} \sup \rho(G) = 1$, when G has $\delta(G) \geq 3$, G connected, G transitive. (Joint work with R. Klimmek)

B: ALSPACH

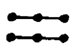
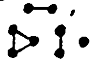
(1/2)-transitive graphs

A graph X is said to be (1/2)-transitive if Aut(X) acts transitively on the vertices and edges of X, but not on the arcs. Some of the recent increase in activity on this topic will be presented.

L.D. ANDERSEN

Subgraphs of K_{2n} suborthogonal to some 1-factorization

A subgraph G of a graph K is suborthogonal to a factorization $\{F_1,\dots,F_f\}$ of K if $|E(G)\cap E(F_i)| \leq 1$ for $1 \leq i \leq f$. It is orthogonal to $\{F_1,\dots,F_f\}$ if $|E(G)\cap E(F_i)| = 1$ for $1 \leq i \leq f$.
A graph is independently 2-dominated if it has two non-adjacent vertices such that each edge is incident with one of these.
The following theorem then holds:
Let G be a subgraph of K_{2n} with at most $2n-1$ edges. Then G is suborthogonal to some 1-factorization of K_{2n}, except if

(a) $|E(G)| = 2n-2$ and G is  ,
or, for n=3, G is  or  , or

(b) $|E(G)| = 2n-1$ and either G is independently 2-dominated, or G is  , or G is one of some exceptions for $n \leq 4$.

Gefördert durch DFG Deutsche Forschungsgemeinschaft

T. ANDREAE

Cartesian products of graphs as spanning subgraphs of de Bruijn graphs

This is joint work with Michael Nölle and Gerald Schreiber (TU Hamburg-Harburg). For Cartesian products $G=G_1\times\ldots\times G_m$ ($m\geq 2$) of nontrivial connected graphs G_i and the n-dimensional base B de Bruijn graph $D=D_B(n)$, we investigate whether or not there exists a spanning subgraph of D which is isomorphic to G. We show that G is never a spanning subgraph of D when n is greater than three or when n equals three and m is greater than two. For n=3 and m=2, we can show for wide classes of graphs that G cannot be a spanning subgraph of D. In particular these non-existence results imply that $D_B(n)$ never contains a torus (i.e., the Cartesian product of $m\geq 2$ cycles) as a spanning subgraph when n is greater than two. For n=2 the situation is much better: We can prove a sufficient condition for a Cartesian product G to be a spanning subgraph of $D=D_B(2)$. As one of the corollaries we obtain that a torus $G=G_1\times\ldots\times G_m$ is a spanning subgraph of $D=D_B(2)$ provided that $|G|=|D|$ and that the G_i are cycles of even length. These results improve some of the results previously obtained by M.C. Heydemann et al (Proceedings of the 1992 International Conference on Parallel Processing) and M. Nölle and G. Schreiber (3. PASA Workshop Bonn, 1993). We also apply our results to obtain embeddings of relatively small dilation of popular processor networks (as tori, meshes and hypercubes) into de Bruijn graphs of fixed small base.

R. BODENDIEK

Labelings of graphs

This talk deals with (a,d)-antimagic graphs, $a,d\in\mathbb{N}$. In the case of a connected finite graph $G=(V,E)$, $|V|\geq 3$, $|E|\geq 2$, it is shown that it is possible to determine classes of (a,d)-antimagic graphs by means of applying facts, concepts and methods of number theory. This method is so good that we show that every tree of even order ≥ 4 cannot be (a,d)-anti-

Gefördert durch DFG Deutsche Forschungsgemeinschaft

magic and that the class of all (a,d)-antimagic parachutes $P_{g,b}$ arising from a wheel $W_{g+b}=1+C_{g+b}$, $g\geq 3$, $b\geq 1$, by deleting b spokes is infinite. The great advantage of this method is that it can be applied to each class of connected graphs of at least 3 vertices and 2 edges.
The concept of (a,d)-antimagic graph is also extended to infinite graphs. Although relatively little is known it holds, for instance, that every infinite n-ary tree $T_n=(V_n,E_n)$, $n\geq 1$, is $(n(n+1)/2,n^2+1)$-antimagic.

A. BROUWER

Spectrum and connectivity of graphs

Proposition (B&Mesner 1985): A strongly regular graph of valency d has vertex connectivity $\kappa=d$.
Proposition (B 1993): The subgraph of a generalized polygon consisting of all vertices in general position w.r.t. ('far away from') a point or line or flag is connected (except when it is not - the four exceptions are explicitly known).
Proposition (Alon&B 1993, unpublished): A regular graph of valency d has toughness $t\geq\frac{d}{\lambda}-2$ where λ is the maximum of the absolute values of the eigenvalues other than d.
Conjecture: $\frac{d}{\lambda}-2$ can be replaced by $\frac{d}{\lambda}-1$ (that would be best possible).

W. DEUBER

Circle chromatic number of a graph

(Joint with Xuding Zhu) Given a graph (G,w) with weight w on the vertices. The circle chromatic number of G is the length of the shortest circle such that there exists an assignement of arcs to the vertices of G such that (i) length $\mathrm{arc}(x)\geq w(x)$ (ii) if $\{x,y\}\in E(G)$ then $\mathrm{arc}(x)\cap \mathrm{arc}(y)=\emptyset$.- Note that this models the greenlight phases on a street crossing.
We indicate certain inequalities concerning various chromatic numbers and relate them to perfect graphs of various kinds.

R. DIESTEL

The growth of infinite graphs

The growth of infinite graphs has been studied extensively for the two extreme cases when the graph is either locally finite or rayless. The talk explores two definitions of growth for graphs with rays and vertices of infinite degree, one due to Halin ("bounded graphs"; cf. Halin's bounded graph conjecture), one other to Thomassen ("finitely spreading graphs"). The two concepts turn out to be surprisingly related (as conjectured by Thomassen): Up to a single discriminator, they are equivalent.
The proof of this develops further techniques that were developed for the recent (1990) proof of the bounded graph conjecture by Leader and the speaker.

Y. EGAWA

Contractible cycles in graphs with girth at least 5

I will discuss the following result which was conjectured by C. Thomassen:
Theorem: Let $k \geq 4$ be an integer, and let G be a k-connected graph with girth at least 5. Then G contains an induced cycle C such that G-V(C) is (k-1)-connected.
This Theorem follows from the following proposition.
Proposition: Let k,G be as in the Theorem, and suppose that each k-contractible edge is contained in a cycle of length 5. Then G contains an induced cycle C of length 5 or 6 such that G-V(C) is (k-1)-connected and $|N(x) \cap V(C)| \leq 1$ for all $x \in V(G)-V(C)$.

P. ERDÖS

Some of my favourite problems in graph theory

Here I just state a few of the problems I presented in my talk.
Faber, Lovasz, and I conjectured more than 20 years ago that the chromatic number of the union of n edge disjoint complete graphs of order n is n. I offer 500 dollars for a proof or

disproof. Recently Jeff Kahn proved that the chromatic number is $n(1+o(n))$. I gave him a consolation price of 100 dollars.

Gallai and I conjectured many years ago that the edges of any graph of n vertices can be covered by cn cycles and edges. We easily proved this with cn log n instead of cn.

Gyarfas, Pyber, and I proved that if we color the edges of a $K(n)$ by r colors then the edges of our $K(n)$ can be covered $cr^2 \log r$ monochromatic cycles.

Color now the edges of a $K(n,n)$ by r colors. Is it true that the edges can be covered by $f(r)$ monochromatic cycles where $f(r)$ depends only on r. This problem should be decided!

Gyarfas and I asked: Let $f(n)$ be the smallest integer for which every $G(n;f(n))$ with n vertices and $f(n)$ edges contains a cycle of size 2^r for some r. We think $f(n)/n\to\infty$ but pretty slowly. Clearly 2^r could be replaced by any infinite sequence $u_1<u_2<\dots$ and the same question could be asked. The answer will no doubt very much depend on the sequence $u_1<u_2<\dots$.

A. FRANK

Increasing connectivity of digraphs

Let $G=(V,E)$ be a finite digraph. G is called k-connected if there are k openly disjoint paths from x to y for every pair of nodes x,y $(k\le|V|-1)$. By Menger's theorem, this is equivalent to requiring that $|V-(X\cup Y)|\ge k$ for every one-way pair (X,Y) of subsets of V. ((X,Y) is called a one-way pair if $X\ne\emptyset\ne Y$, $X\cap Y=\emptyset$ and there is no edge from X to Y.)

The deficiency of a one-way pair is defined by $P_{def}(X,Y)=k-|V-(X\cup Y)|$. We say that two one-way pairs (X,Y) and (X',Y') are independent if at least one of $X\cap X'$ and $Y\cap Y'$ is empty.

Theorem: A directed graph can be made k-connected by adding at most γ new edges if and only if $\Sigma(P_{def}(X,Y):(X,Y)\in F)\le\gamma$ holds for every family F of pairwise independent one-way pairs.

This is a joint result with T. Jordan and will appear in J. Combin. Theory, Ser. B, under the title: Minimal edge-coverings of pairs of sets.

J. GIMBEL

Coloring graphs with bounded genus and girth

(Joint work with C. Thomassen) Suppose $\chi(S_g')$ represents the largest chromatic number of all triangle-free graphs of genus g. We show $c_1 g^{1/3}/\log g \leq \chi(S_g') \leq c_2(g/\log g)^{1/3}$ where c_1 and c_2 are positive constants. Further, we show that if $k \geq 4$ and G is a triangle-free graph of bounded genus, then we can tell in polynomial time if $\chi(G) \leq k$. Finally, we show that if G embeds on the double torus and has girth 6 then $\chi(G) \leq 3$.

R. HÄGGKVIST

Trees in Dirac graphs

1. First of all consider the family of n-order graphs, n odd, with minimum degree at least $(n-1)/2$. It is well known that P_n is a subgraph of every such graph. Which additional spanning subgraphs are unavoidable? Such graphs must be subgraphs of $2K_{(n-1)/2}+K_1$ and $K_{(n-1)/2,(n+1)/2}$. Consequently they must be bipartite with almost equal sized parts, i.e. nearly balanced, and bisectable, i.e. there should exist a vertex whose removal leaves a graph which is a spanning subgraph of $2K_{(n-1)/2}$.

Conjecture 1: Every bisectable nearly balanced tree with maximum degree at most $\sqrt{n}$ is unavoidable.

2. Conjecture 2: The graph consisting of two $(2k+2)$-cycles joined at a vertex is unavoidable when $n=4k+3$.

3. Theorem (Goodall+H): Every large enough graph on 2^p-1 vertices, each of degree at least $2^{p-1}+3p2^{\lceil 3p/4\rceil+3}$ contains a spanning complete binary tree.

Conjecture 3: Every graph with 2^p-1 vertices, each of degree at least 2^{p-1} contains a spanning complete binary tree.

Conjecture 4: Every n-order graph with minimum degree at least $n/2+\sqrt{n}$ contains every n-order tree with maximum degree at most $\sqrt{n}$.

Conjecture 5: n odd. Every n-order Dirac graph contains every bisectable n-order tree with maximum degree at most $\sqrt{n}$.

R. HALIN

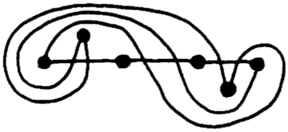
Minimization problems for infinite n-connected graphs

A graph is called n-minimizable if it has a spanning subgraph H which is minimally n-connected (i.e. H is n-(vertex) connected but loses this property if any edge is deleted). Several approaches are discussed to get criteria for an infinite n-connected graph to be n-minimizable. The effect on the n-minimizability is studied if elementary operations (deleting or adding edges, deleting or adding vertices of finite degree) are applied. It is shown that, if an n-connected graph G is pasted together from two n-connected graphs H, J along a common finite subgraph, then G is n-minimizable if and only if H and J are n-minimizable. From this result the properties are exhibited which a tree-decomposition with n-minimizable members must have in order to guarantee that the ground graph is n-minimizable. We get a sharpening of a theorem due to Rüdiger Schmidt saying that every n-connected rayless graph is n-minimizable.

H. HARBORTH

Drawings of the cycle graph

It is asked for the existence of crossing r-regular drawings G(G) of the cycle graph C_n, that is, for drawings (two edges have at most one point in common) where every edge has exactly r crossings, o $r \leq n \leqq 3$, and $r \equiv 0(2)$ for $n \equiv 1(2)$. For fixed r it suffices to consider $r+3 \leqq n \leqq 2r+5$ to prove the existence for $n \geqq r+3$. Some infinite classes and some crossing r-regular drawings are presented. For $r \leqq 9$ the only missing cases are $D(C_{10})$ and $D(C_{14})$ for r=6.



$D(C_6)$, r=2.

A. HUCK

Independent trees

A well-known conjecture states the following: Let G be a k-connected finite graph (directed or undirected) and let s be a vertex of G. Then there exist k spanning trees $T_1, \ldots,$ T_k in G (directed towards s if G is directed) such that for each vertex $x \neq s$, the k paths in $T_1, \ldots, T_k$ from x to s are pairwise openly disjoint. - Some results dealing with this conjecture are presented. For instance, the directed version is disproved for each $k \geq 3$.

J.P. HUTCHINSON

On three-colouring graphs embedded on surfaces with all faces even-sided

We discuss the following theorem: Let G be embedded on an orientable surface of genus $g>0$ with all faces having an even number of sides. If all noncontractible cycles have length at least 2^{3g+5} then G can be 3-coloured. The bound of 3 colours is best possible; the noncontractible cycle length is surely not best possible; the theorem does not hold for nonorientable surfaces.

W. IMRICH

Hamming graphs and Cartesian products

This talk presents ideas recently introduced by several authors (Graham, Winkler, Feder, ...) in the investigation of Cartesian products of graphs, binary Hamming graphs, Hamming graphs, median graphs, quasimedian graphs, and l_1-graphs. In particular, three relations (θ, τ, σ) on the edge set of a graph play an important role in claryfying the interconnection between these classes and in the development of efficient algorithms for recognizing them.

F. JAEGER

Cycle double covers: an algebraic point of view

We apply the theory of spin models for link invariants to connected 4-regular plane graphs. If $c(L)$ denotes the number of diagonals of such a graph L and $D=\pm 2^m$, we obtain an expression for $D^{c(L)}$ as a normalized partition function of a spin model on L whose spins are vectors of $GF(2)^{2m}$ and whose local weight function is $W(x,y)=(-1)^{Q(x+y)}$, where Q is a quadratic form. Then we obtain a similar expression for the Penrose polynomial of L. Since when L is the medial graph of a cubic graph G this polynomial for the value k of the variable counts the k-colored cycle double covers of G, we obtain a proportionality relation between the number of 2^m-colored cycle double covers of G (when $m\equiv 0$ or $m\equiv 3 \bmod 4$) and the number of $GF(2)^{2m+1}$-flows of G where each flow value has Hamming weight congruent to 2 mod 4. We discuss the possibility to generalize this formula in relation with the Cycle Double Cover conjecture.

H.A. JUNG

On the circumference of tough graphs

A graph G with minimum degree δ and toughness $t=\min(|S|/\omega(G-S)$: S cut set of G$)\geq 1$ is hamiltonian or has a cycle C such that $|C|\geq(t+1)\delta+1-t$.

L. LOVASZ

Random walks

The theory of random walks on finite graphs has become very important in computer science. One of the main applications concerns sampling: we want to generate a (say) uniformly distributed random element from a large finite set. The method consists of defining an appropriate regular graph on this set, doing a random walk on this graph, and then stopping after an appropriate number of steps. The last point will be approximately uniformly distributed.
The crucial issue is to know how long we have to walk. This is determined by the mixing rate of the walk. One can use eigenvalue techniques to estimate this rate, but there are also purely combinatorial methods.
Recently Peter Winkler and the lecturer studied more general stopping rules, where the time of stopping may depend on the history of the walk. It turns out that such rules give only a constant speedup, but they provide new ways of estimating the mixing rate.

W. MADER

Degree and local connectivity in digraphs

It is proved that for every positive integer k there is an $f(k)$ such that every finite digraph of minimum outdegree $f(k)$ contains vertices x,y joined by k openly disjoint paths from x to y.

B.D. McKAY

Advances in classical graph Ramsey theory

The Ramsey number $R(s,t)$ is defined to be the least positive integer n such that every n-vertex graph contains either a clique of order s or an independent set of order t. We will describe some recent advances in methods to determine Ramsey numbers or improve bounds on them. The most important new results are $R(4,5)=25$ and $R(5,5)\leq 49$. We also indicate our reasons for making the conjecture $R(5,5)=43$.

B. MOHAR

Locally planar graphs

Embeddings of graphs in the plane are well understood. Basic results are due to Whitney and Tutte. Extensions of their results to graphs on other surfaces will be discussed. This will lead to a notion of locally planar embeddings. Graphs with such embeddings share many properties with planar graphs. In particular, they have small chromatic number, spanning trees with small maximal degree, etc.. Some recent results of this type will be presented.

H.M. MULDER

Median procedure on graphs

(joint with F.R. McMorris & F.S. Roberts) Let $\pi=v_1,v_2,\ldots,v_p$ be a sequence of vertices in a connected graph $G=(V,E)$. A vertex x is a <u>median</u> of π if it minimizes the distance sum $\sum_{i=1}^{p} d(x,v_i)$. And $M(\pi)=\{x \text{ median of } \pi\}$ is the <u>median set</u> of π. If V^* denotes the set of sequences on V, then $M:V^* \to 2^V$ is the <u>median procedure</u> on G. Now M satisfies the following

simple conditions: (A) $M(\pi)=M(\pi')$ for any permutation π' of π (Anonymity), (B) $M(u,v)=I(u,v)=\{x \mid d(x,u)+d(x,v)=d(u,v)\}$, the interval between u and v (Betweenness), (C) $M(\pi,\rho)=M(\pi)\cap M(\rho)$ if $M(\pi)\cap M(\rho)\neq\emptyset$ (Consistency). - The problem arises on which connected graphs G any function $L:V^* \to 2^V$ satisfying (A), (B), and (C) is precisely the median procedure on G. One simple example is provided by the complete graphs, but in general the question is open.
A median graph is a graph in which $|M(u,v,w)|=1$ for all u,v, w. Relying on the structure theory for median graphs (developed by HMM), we are able to show that L satisfying (A), (B),(C) on a cube-free median graph is precisely the median procedure. For arbitrary median graphs we need a rather technical extra condition.

J. NESETRIL

Generalized colorings

A homomorphism f from a graph G into a graph H is also called H-coloring. We say that a H-coloring has a bounded tree width duality if there exists k such that a graph G is H-colorable iff any graph F of tree width $\leq k$ which is G-colorable is also H-colorable. - We have the following: Theorem (Feder, Vardi; Hell, Nesetril, Zhu): If a H-coloring has a bounded tree width duality then there exists a polynomial algorithm for a H-coloring of a graph. - Theorem (Nesetril, Zhu): For undirected graphs a H-coloring has a bounded tree width duality iff H is bipartite.

H.J. PRÖMEL

Counting triangle-free graphs

An important result of Erdös, Kleitman, and Rothschild says that almost every triangle-free graph has chromatic number 2. In this talk we study the asymptotic structure of graphs in $Forb_{n,m}(K_3)$, i.e., in the class of triangle-free graphs on n vertices having $m=m(n)$ edges. In particular, we prove that an analogue to the Erdös-Kleitman-Rothschild result is true whenever $m \geq cn^{7/4}\log n$ for some constant $c>0$. This can be used to derive an asymptotic formula for the number of triangle-free graphs with so many edges. On the other hand, it is shown that almost every graph in $Forb_{n,m}(K_3)$ has at least chromatic number 3, provided that $c_1 n<m<c_2 n^{3/2}$, where $c_1,c_2>0$ are appropriate constants. (These are joint results with Angelika Steger, Bonn.)

B. RICHTER

Covering genus-reducing edges with Kuratowski subgraphs

Vollmerhaus and Glover independently conjectured that a genus-minimal graph G can be covered by subdivisions of $K_{3,3}$ and K_5. An example is given of a graph that minimally does not embed in the torus and yet two edges are in no subdivision of either $K_{3,3}$ or K_5. However, if the non-orientable genus of G-e is less than that of G, then e is in a subdivision of either $K_{3,3}$ or K_5.

G. RINGEL

Euler Hamilton connection

Let G be a maximal planar graph with n edges. Then there exists a labelling of the edges by 1,2,...,n such that any two consecutive numbers are the labels of two adjacent edges. This concept is a substitute (or generalization) of the existence of an Euler trail or circuit or a Hamilton cycle or path. - Independently, the following theorem were mentioned: Each maximal planar graph is edge-decomposable into two trees.

N. ROBERTSON

Branch-width 3 graphs and binary matroids

This includes joint work with Ellis Johnson, Sunil Chopra, and Jack Dharmatilake, and is based on Dharmatilake's recent thesis (O.S.U. 1994). Branch-width is a notion of tree-structure of a graph that readily generalizes to matroids. Branch-width ≤ 2 matroids coincide with series-parallel graphs, but branch-width ≤ 3 matroids (forming a minor-closed class) have a richer structure. There is a natural reduction to 3-connection, a summing operation on 8 small graphs generates the class, and there are 4 obstacles (minor-minimal branch-width ≥ 4). A similar analysis, including extensive computer work, finds 3 summing operations, 16 generating binary matroids, and 10 obstacles. This latter part is work in progress.

B. ROTHSCHILD

A canonical Ramsey theorem for unary algebras

(joint with W. Deuber and B. Voigt) We consider unary algebras (X,χ), where X is a finite set and $\chi:X\to X$, and X is ordered (e.g. $X=\{1,2,\ldots,n\}$). The ordering is used to establish orderings of subalgebras. Then we show that: For any algebras K,L, there is an algebra N so that if the K-subalgebras of N are arbitrarily colored, there is an L-subalgebra L' so that all its K-subalgebras are colored in a 'canonical' way. The canonical patterns are exactly those determined by subalgebras of K. For example, if H is a subalgebra of K, then two copies of K in L' have the same color exactly when they overlap in L on H, where H occupies the same 'position' in each K (determined by the ordering).

G. SABIDUSSI

Homomorphisms and Cayley graphs

(joint work with Claude Tardif) In analysing the ultimate independence ratio of a graph G (Hahn, Hell, and Poljak 1993) an important special case arises when the cartesian square G^2 has a homomorphism into G, i.e., $G\leftrightarrow G^2$, where $\leftrightarrow$ denotes homomorphic equivalence. A class of such graphs are the normal Cayley graphs Cay(A,B) (where B is a normal subset of the group A), the homomorphism $G^2\to G$ being given by $(u,v)\mapsto uv$ (product in A). Rather surprisingly, this statement has a kind of converse, which can be described as follows. Call an automorphism σ of G a shift if $\sigma(x)$ is adjacent to x for any $x\in V(G)$; denote the set of all shifts by S_G. Theorem:

(i) Cay(AutG,S_G) is a normal Cayley graph; (ii) if G is a core (i.e. all its endomorphisms are automorphisms), then $G \leftrightarrow G^2$ iff $G \leftrightarrow$ Cay(AutG,S_G). For arbitrary G we obtain that $G \leftrightarrow G^2$ iff $G \leftrightarrow$ Cay(AutC(G),$S_{C(G)}$), where C(G) is the core of G in the sense of Hell and Nesetril (1991). The proof uses a result of Pultr (1970) to the effect that $G \leftrightarrow G^2$ iff G is homomorphically equivalent to its endomorphism graph.

P. SEYMOUR

A proof of the four-colour theorem, Part 1

In 1977, Appel and Haken proved the four colour theorem, that every loopless planar graph is 4-vertex-colourable. Their proof uses a computer, but in addition even the non-computer part is extremely difficult to verify. In joint work with N. Robertson, D. Sanders, and R. Thomas, we found a new computer proof. We use the same approach as Appel and Haken, but the details are simpler and more easily checked. We found a set of 631 "configurations", and proved (a) none of them appear in a minimal counterexample, (b) at least one of them appears in every planar triangulation with suitable connectivity properties. Since every minimal counterexample must possess these connectivity properties, the theorem follows. In this talk we give some details of part (a).

V. T.SOS

Quasirandom graphs and hereditary resp. hereditarily extended properties

(Joint work with M. Simonovits) Quasirandom graphs are defined by a class of equivalent graph properties (possessed also by random graphs). One basic question is which graph properties P imply randomness or are equivalent to quasirandomness. Here we investigate properties which do not imply quasirandomness on their own, but do imply (are equivalent to) quasirandomness, if they hold not only for the whole graph G_n but also for every sufficiently large spanned subgraph $H_m \subseteq G_n$. E.g. we have the Theorem: Let L_ν be a fixed graph on ν vertices, $N_L(G_n)$ be the number of not necessarily induced, labelled copies of L_ν contained in G_n. If for a graph sequence (G_n) there is a γ s.t. (*) $N_L(H_m)=\gamma m^\nu + o(n^\nu)$ holds for any spanned $H_m \subseteq G_n$ then (G_n) is a quasirandom sequence of probability $p=p(\gamma)$. As a consequence we get e.g. that if (*) holds for some L_n then it holds for any other sample graph L^*_μ with some appropriate constant $\gamma(p,L^*)$. An analogous theorem for the number of induced copies does not hold in general. We also investigate this more complex problem. We can formulate our results in terms of generalized random resp. generalized quasirandom graphs.

M. STIEBITZ

Decomposition and colorings of graphs

At the International Conference on Combinatorics held in Keszthely in July of 1993 the following question was asked by N. Sauer: If the edge set of a graph G can be partitioned into sets E_1 and E_2 such that the connected components of the subgraph of G induced by E_1 are stars and the subgraph of G induced by E_2 is a forest, is it true that G is 3-colorable? We present two general results about colorings, which, in particular, provides an affirmative solution to Sauer's problem.

R. THOMAS

A new proof of the Four Color Theorem, Part 2

This is a continuation of Paul Seymour's talk. We discuss our proof that a certain set U of reducible configurations of size 631 is unavoidable, that is, every internally 6-connected planar triangulation contains a member of U. We also describe a quadratic algorithm to four-color planar graphs. This is joint work with Neil Robertson, Daniel P. sanders and Paul Seymour.

C. THOMASSEN

List-coloring planar graphs

A graph G is k-choosable if it satisfies the following: If a list of k-colors is assigned to every vertex, then it is possible to color the vertices such that each vertex receives a color from its list and neighboring vertices get different colors. In 1979 Erdös, Rubin and Taylor conjectured that every planar graph is 5-choosable. We present a short proof of this conjecture. The method extends to the following: Every planar graph of girth 5 is 3-choosable. This immediately implies Grötzsch's theorem that every planar graph with no triangle is 3-choosable. Finally, for every fixed surface S there exists a natural number m such that every graph on S with edge-width at least m is 6-choosable. The results are best possible except that "6-choosable" may be replaced by "5-choosable" in the last result.

B. TOFT

Choosability versus chromaticity

The starting point of my lecture was the following string of well known inequalities: $\chi(G)\le ch(G)\le col(G)\le Mad(G)+1\le\Delta(G)+1$. χ is the chromatic number, ch the choice number (or list-chromatic number), col the colouring number, Mad the maximum average degree in a subgraph, and Δ the maximum degree. These five graph constants are all different. The first two are defined in terms of colourings, the last three in terms of degrees. Moreover, χ and ch behave similarly w.r.t. complexity, Erdös-deBruijn, Brooks and surfaces (only for the sphere the maximum χ differs from the maximum ch). However, a theorem of Noga Alon (Proc. Brit. Comb. Conf. 1993) indicates that ch behaves more like col than like χ. In particular, $ch(G_i)\to\infty$ if and only if $col(G_i)\to\infty$. For example, all d-regular graphs have large ch for d large. This implies that $ch(P)=\infty$, where P is the unit-distance graph of the plane. It is unknown if ch(P) is countable.

H. TVERBERG

On a new approach to the Erdös-Faber-Lovasz problem

Let the edge set of a graph G be the disjoint union of sets, each of which forms the edge set of an n-clique. Then the E.-F.-L problem consists in proving that $\chi(G)=n$. This problem seems hard although Jeff Kahn has proved that $\chi(n)=n(1+o(1))$. The purpose of the talk is to show the relation of the problem to the following geometric fact (proved by H.T. in 1964): Let S be a set of $(r-1)(d+1)+1$ points in R^d. Then it is possible to split S as $S_1 \cup S_2 \cup \ldots \cup S_r$, so that $\operatorname{conv} S_1 \cap \ldots \cap \operatorname{conv} S_r \neq \emptyset$. We will also sketch Sarkasia/Onn's recent proof of the geometric theorem.

H.-J. VOSS

Many short cycles in graphs

Only undirected graphs are to be considered. The results presented here are based on a common research work with A. Brandstädt, Duisburg. One of four results is:

1. Every cubic graph of order n contains $\geq n/(8 \log n)$ vertex-disjoint cycles of lengths $\leq 8 \log n$. - Related results have been obtained for the class of all graphs which have only vertices of valencies in the interval $[3,\Delta]$, where $\Delta \geq 3$ is a given integer. The complete bipartite graph $K_{3,n-3}$ shows that the upper bound Δ cannot be dropped. - If cycles of lengths ≤ 4 are excluded then similar bounds can again be obtained which do not depend on the maximum degree of the graph. So it holds:

2. Every graph of order n with minimum degree ≥ 3 and girth ≥ 7 contains $\geq (\sqrt{2n})/(8 \log n)$ vertex-disjoint cycles of lengths $\leq 12 \log n$.

3. Every graph of order n with minimum degree ≥ 4 and girth ≥ 5 contains $\geq (\sqrt{n})/(8 \log n)$ vertex-disjoint cycles of lengths $\leq 8 \log n$.

Similar results have been proved with respect to many vertex-disjoint subgraphs U_i of given cyclomatic number z.

D.H. YOUNGER

The Birkhoff-Lewis equations

In 1946, G.D. Birkhoff and D.C. Lewis described a system of linear equations which relates two types of chromatic polynomials - constrained and free - for a planar map bounded by a disc. In 1988, Tutte gave a reformulation of these equations in terms of the planar partitions of an abstract ring of n vertices. In the Tutte system, the coefficient matrix A has P,Q^{th} entry equal to $\lambda^{|P\vee Q|}$, where "$\vee$" denotes the join, and P and Q run over all $\binom{2n}{n}/(n+1)$ planar partitions of an n-ring. This paper describes how to diagonalize matrix A. Specifically, we describe the entries of a matrix H and of a diagonal matrix D such that $H^TAH=D$. Even though A is symmetric and real, the matrix H described here is not orthogonal - H^t is not its inverse. This is joint work with Ricardo Dohab, who received his Ph.D. for this project. Tutte's theory for det A is a part of the proof of correctness of the formula for the entries in H.

Ungelöste Probleme

J.A. BONDY, R. HÄGGKVIST

Let G be a 2k-regular simple graph on n vertices.

Conjecture 1. G has a 2-factorization consisting of at most $(kn)/(2k+1)$ circuits.

Conjecture 2. G has a 2-factor consisting of at most $n/(2k+1)$ circuits.

Conjecture 3. G has a 2-factor which contains a circuit of length at least $2k+1$.

Conjecture 4. If $k=10^{10}$, G has a 2-factor which contains a circuit of length at least five.

Remarks: (a) Conjecture 1 $\Rightarrow$ Conjecture 2 $\Rightarrow$ Conjecture 3 $\Rightarrow$ Conjecture 4. (b) Conjecture 1 also implies Hajôs' Conjecture, that every even simple graph on n vertices admits a decomposition into at most $(n-1)/2$ circuits, in the case of regular graphs.

Y. EGAWA

Conjecture (K. Ando): If G is a 3-connected, $K_{1,3}$-free graph of order n, then for any given partition $n=n_1+\ldots+n_k$ of n into positive integers $n_1,\ldots,n_k$, there exists a direct-sum decomposition $V(G)=V_1\dot{\cup}\ldots\dot{\cup}V_k$ of V(G) into subsets $V_1,\ldots,V_k$ such that for each $1\leq i\leq k$, $|V_i|=n_i$ and the subgraph induced by V_i is connected.

P. ERDÖS

1) Let f(n) be the largest integer for which one can find n points $x_1,\ldots,x_n$ in the plane for which for every x_i there are $\geq f(n)$ other points equidistant from x_i. Is it true that $f(n)\geq n^c$ for some c>0. If such a c does not exist then $x_1,\ldots,x_n$ determine at least $n^{1-o(1)}$ distinct distances, in fact, there is an x_i for which the number of distinct distances from x_i is $>n/f(n)>n^{1-o(1)}$.

2) I once asked: Color the edges of K(7) by three colors so that every color has 7 edges. Prove that it can not happen that every triangle has exactly two colors. Alsbach proved this. Vera Sos and Simonovits have a long paper on this subject (Combinatorica, Vol. 3 or 4).

3) A family of sets $\{A_i\}$ is said to have property B (or is 2-chromatic) if there is a set S which meets every A_i and contains none of them. - Assume $|A_i|=n$, f(n) is the smallest set which does not have property B. f(3)=7, f(4) is unknown, $19\leq f(4)\leq 23$. - $c_1 2^n n^{1/3}<f(n)<c_2 n^2 2^n$. The upper bound is due to me, the lower to Beck. - Now assume $A_i\subset S$, $|S|=m$. f(n;m) is the smallest three chromatic family of sets. $f(n;2m)=\binom{2m}{n}$. As m increases I am sure f(n;m) drops for a long time, and the minimum is reached perhaps around $m=cn^2$.

A. FRANK, T. JORDAN

1. Let G=(V,E) be a k-connected, k-regular graph for which |V| is even and $|V|\geq 2k+2$. Then there exists a perfect matching M (in the complement of G) so that G+M is (k+1)-connected! (Jordan proved this for k=3. For odd k, if |V|=2k, the statement is not true: take $K_{k,k}$, the complete bipartite graph.)

2. (Robert Connelly) Let G be a 3-connected graph which is the union of two spanning trees. Then G can be built up from K_4 by a sequence of the following operations: (a) Pick up an edge e=uv, (b) subdivide e by a new vertex z, (c) connect z to an existing vertex different from u and v.

R. HÄGGKVIST

Recall that every graph G has a well defined closure, c(G), obtained by recursively joining pairs of nonadjacent vertices with degree sum at least $|V(G)|$ by an edge.
Conjecture: Every graph on 4k vertices, each of degree at least 2k admits a partition of its vertex set into two 2k-sets, both of which induce a graph with complete closure.

H. HARBORTH

Does there exist a drawing of the complete graph K_n in the plane (two edges have at most one point in common) which has $\binom{n}{4}$ crossings (that is, the maximum) such that no edge or at most one edge is without crossings?
Can every planar graph be realized in the plane such that all edges are straight line segments of integer length?

A. HUCK

Let G be a cubic graph. For each spanning Eulerian subgraph H of G (not necessarily connected), we define: $\omega(G,H)$=number of components of H with an odd number of vertices. $\omega(G)=\min\{\omega(G,H)$; H spanning Eulerian subgraph of G$\}$ is called the <u>oddness</u> of G. Conjecture: If V(G) can be partitioned into n disjoint paths then $\omega(G)\leq 2n$. (This is proved for n=1.)

J. HUTCHINSON

What is the maximum possible chromatic number of rectangle-visibility graphs? A rectangle-visibility graph is one whose vertices can be represented each by a closed rectangle in the plane with sides parallel to the axes, with interior disjoint from every other rectangle, and with two vertices adjacent if and only if there is an unobstructed horizontal or vertical bamd of positive width joining one rectangle to the other.

F. JAEGER

Let G be a cubic cyclically 4-edge-connected graph.
Conjecture 1 (F.J., Boca Raton 1974): There exists a partition $\{A,B\}$ of $V(G)$ such that both induced subgraphs G_A, G_B are trees. - Conjecture 2 (Peter Ungar, Graph Theory and Related Topics, 1977): There exists a partition of $E(G)$ into two trees. - The two conjectures are easily seen to be equivalent and are true for planar graphs by a result of Whitney which asserts that the dual graph is Hamiltonian.

W. MADER

Conjecture: Every finite simple undirected graph of minimum degree $3n-4$ contains an n-connected subgraph, and this minimum degree is best possible. - Proved for all $n \leq 7$.

B. MOHAR

Suppose that a graph G can be written as a union of two edge-disjoint spanning trees. Prove that the line graph of G is Hamiltonian.
Carsten Thomassen has pointed out that a proof of his conjecture that the line graph of every 4-edge-connected graph is Hamiltonian only uses the fact that such graphs have two disjoint spanning trees. That proof thus also solves the above problem.

C. NASH-WILLIAMS

Let G be a locally finite connected infinite graph. Let L_1, $L_2, \ldots$ be an infinite sequence of disjoint finite subsets of $E(G)$. - Let $\tilde{r}$ denote an infinite sequence $r_1, r_2, \ldots$ of integers such that $0 \leq r_i \leq |L_i|$ for $i=1,2,\ldots$. We define an <u>$\tilde{r}$-set</u> to be a set $S=S_1 \cup S_2 \cup \ldots$ such that $S_i \subsetneq L_i$ and $|S_i| = r_i$ for $i=1,2,\ldots$. We shall say that $\tilde{r}$ is <u>bad</u> if $G-S$ is disconnected for every $\tilde{r}$-set. We shall say that $\tilde{r}$ is <u>just-bad</u> if $\tilde{r}$ is bad and there exists an $\tilde{r}$-set S such that the number of components of G-S is finite. We shall say that $\check{r}$ <u>dominates</u> a sequence $r'_1, r'_2, \ldots$ if $r_i \geq r'_i$ for $i=1,2,\ldots$. - Must every bad sequence dominate some just-bad sequence? In the event of the answer being negative, would it become affirmative if we made the additional hypothesis that the sets $X_1, X_2, \ldots$ are disjoint, where X_i is the set of those vertices which are incident with at least one element of L_i.

B. RICHTER

1. Let Γ be a family of simple closed curves such that if $C, C' \in \Gamma$, then $C \cap C' \neq \emptyset$. Suppose further that no three meet at a single point. Let $f(n) = \min\limits_{|\Gamma|=n} \sum\limits_{\substack{C,C' \in \Gamma \\ C \neq C'}} |C \cap C'|$. What is $f(n)$?

Known: $\frac{3}{2} \leq \lim\limits_{n\to\infty} f(n)/\binom{n}{2} \leq 2$ and the limit exists.

2. Let G be a graph embedded in a surface Σ, which is not the sphere. The <u>representativity</u> of G is $\min\{|\gamma \cap G| : \gamma$ is a noncontractible simple closed curve in $\Sigma\}$. Show: If $\rho \geq 3$ and F, F' are faces of G, then exists a cycle C in G bounding a disc Δ such that $F \cup F' \subseteq \Delta$?

G. RINGEL

Let G be a graph with n edges. And let be given a labelling of the edges by $1,2,\ldots,n$. We define the valence of a vertex P as the sum of the labels of the edges incident with P. G is called <u>magic</u> (resp. <u>antimagic</u>) if there exists a labelling where all vertices have the same (resp. distinct) valence. - Conjecture: Each connected graph $\neq K_2$ is antimagic.

N. ROBERTSON

Suppose (G,S) is an embedding of a graph G on a homotopically nontrivial surface S. We say (G,S) is k-representative if every nontrivial circuit C in S meets G in at least k points. It is proved in [1] that given an embedding (H,S), there exists an integer f(H,S) such that any f(H,S)-representative embedding (G,S) includes (H,S) as a monor. Surface minors are formed by deleting edges, contracting non-loop edges of G and taking a homeomorphism of S. The bound f(H,S) from |1| is far from best possible and it is a serious research problem to bring it to the correct order of magnitude, both in the general case and for specific instances. Let n be an integer (n>7) and let (G_i,T_i) be non-representative embeddings on the torus; for i=1,2,...,g with disjoint large faces A_i,B_i in (G_i,T_i). Identify in order n-2 vertices of G_i on B_i with n-2 vertices of A_{i+1}, for i=1,2,...,g-1 to obtain an embedding (G,S_g) of a graph G on the surface of genus g. This embedding can be (n-2)-representative, but the complete graph K_n cannot be a minor of G. We may conjecture that if K_n embeds on a surface S, and (G,S) is (n-1)-representative, then (K_n,S) is a minor of (G,S). Even any linear bound would be of interest here. More generally, if H is a simple graph embedded on S and (G,S) is an embedding that is (|V(H)|-1)-representative, it may be conjectured that (H,S) is a minor of (G,S).

A problem of David Barnette, for triangulations, and independently of Xiacya Zha for general embeddings asks if any 3-representative embedding (G,S) on a surface of orientable or unorientable genus at least 2 always contains a nontrivial separating circuit C for S; i.e., $C \subseteq G$ and S-G has two nontrivial components. The most recent results on this problem appear in the very clear paper |2| of Zhao and Zha.

It was conjectured by Scott Randby, in his thesis at Ohio State University (1991), that any 4-connected graph G with a 4-representative embedding (G,S) necessarily contains a topological K_5. This conjecture is true and best possible for the torus, with $K_{5,5}-M_5$ having a 4-representative embedding but not containing K_5 topologically. Here $K_{5,5}-M_5$ is the complete bipartite graph $K_{5,5}$ with a 5-matching M_5 deleted. Randby's upper bound in general is at the 8-representative level.

References:

|1| N. Robertson and P.D. Seymour, Graph Minors. VII. Disjoint paths on a surface, J. Combinatorial Theory, Ser. B, 48 (1990) 212-254.

|2| Xiacya Zha and Yue Zhao, On non-null separating circuits in embedded graphs, Contemporary Mathematics, Vol. 147 (1993) 349-362.

B. TOFT

Let G be a bipartite graph with bipartition (A,B). Suppose that all vertices in A have the same degree d_A and all vertices in B the same degree d_B. Does G have an edge-colouring with colours 1,2,3,... such that for all vertices X of G the colours of the edges at X form an interval? The case $d_A=2$ and $d_B=2k$ with colours 1,2,...,2k is equivalent to Petersen's theorem that any 2k-regular graph is 2-factorizable. The case $d_A=2$ and $d_B=5$ has been settled recently and the case $d_A=2$ and d_B odd is likely to follow similarly. Thus the first open case is $d_A=3$ and $d_B=4$.

Berichterstatter: H. Harborth

Tagungsteilnehmer

Prof.Dr. Martin Aigner
Institut für Mathematik II
Freie Universität Berlin
Arnimallee 3

D-14195 Berlin

Prof.Dr. J. Adrian Bondy
Department of Combinatorics and Optimization
University of Waterloo

Waterloo , Ont. N2L 3G1
CANADA

Prof.Dr. Brian Alspach
Dept. of Mathematics
Simon Fraser University

Burnaby , B. C. V5A 1S6
CANADA

Prof.Dr. Andries E. Brouwer
Department of Mathematics
Technische Universiteit Eindhoven
Postbus 513

NL-5600 MB Eindhoven

Prof.Dr. Lars Dovling Andersen
Institut for elektroniske systemer
Aalborg Universitetscenter
Fredrik Bajers Vej 7E

DK-9220 Aalborg O

Prof.Dr. Walter Deuber
Fakultät für Mathematik
Universität Bielefeld
Postfach 100131

D-33501 Bielefeld

Prof.Dr. Thomas Andreae
Mathematisches Seminar
Universität Hamburg
Bundesstr. 55

D-20146 Hamburg

Dr. Reinhard Diestel
Mathematical Institute
Oxford University
24 - 29, St. Giles

GB-Oxford , OX1 3LB

Prof.Dr. Rainer Bodendiek
Mathematisches Institut
Pädagogische Hochschule Kiel
Olshausenstr. 75

D-24118 Kiel

Prof.Dr. Yoshimi Egawa
Dept. of Applied Mathematics
Science University of Tokyo
1-3 Kagurazaka, Shinjuku-ku

Tokyo 162
JAPAN

Prof.Dr. Paul Erdös
Mathematical Institute of the
Hungarian Academy of Sciences
P.O. Box 127
Realtanoda u. 13-15

H-1364 Budapest

Prof.Dr. Heiko Harborth
Diskrete Mathematik
TU Braunschweig
Pockelsstr. 14

D-38106 Braunschweig

Prof.Dr. Andras Frank
Department of Computer Science
Eötvös University
ELTE TTK
Muzeum krt. 6 - 8

H-1088 Budapest VIII

Prof.Dr. Katherine Heinrich
Dept. of Mathematics
Simon Fraser University

Burnaby, B. C. V5A 1S6
CANADA

Prof.Dr. John Gimbel
Department of Mathematics
University of Alaska

Fairbanks, AK 99775-1060
USA

Andreas Huck
Institut für Mathematik
Universität Hannover
Welfengarten 1

D-30167 Hannover

Prof.Dr. Roland Häggkvist
Dept. of Mathematics
University of Umea

S-901 87 Umea

Prof.Dr. Joan P. Hutchinson
P.O. Box 1782

Silverthorne, CO 80498-1782
USA

Prof.Dr. Rudolf Halin
Mathematisches Seminar
Universität Hamburg
Bundesstr. 55

D-20146 Hamburg

Prof.Dr. Wilfried Imrich
Institut für Mathematik
und Angewandte Geometrie
Montanuniversität Leoben
Franz-Josef-Str. 18

A-8700 Leoben

Prof.Dr. Bill Jackson
Dept. of Mathematical Studies
Goldsmiths' College
New Cross

GB-London , SE14 6NW

Dr. Brendan McKay
Department of Computer Science
Australian National University
P. O. Box 4

Canberra ACT 2601
AUSTRALIA

Prof.Dr. François Jaeger
Laboratoire de Structures Discrètes
Institut IMAG
Université Joseph Fourier
Boîte Postale 53x

F-38041 Grenoble Cedex

Prof.Dr. Bojan Mohar
FNT - Matematika
University of Ljubljana
Jadranska 19

61111 Ljubljana
SLOVENIA

Prof.Dr. Heinz Adolf Jung
Fachbereich Mathematik
Technische Universität Berlin
Straße des 17. Juni 135

D-10623 Berlin

Henry Martyn Mulder
Econometrisch Instituut
Erasmus Universiteit
Postbus 1738

NL-3000 DR Rotterdam

Prof.Dr. Laszlo Lovasz
Department of Computer Science
Yale University

New Haven , CT 06520
USA

Prof.Dr. Crispin S.J.A. Nash-Williams
Dept. of Mathematics
University of Reading
Box 220
Whiteknights

GB-Reading , RG6 2AX

Prof.Dr. Wolfgang Mader
Institut für Mathematik
Universität Hannover
Postfach 6009

D-30060 Hannover

Prof.Dr. Jaroslav Nesetril
Dept. of Mathematics and Physics
Charles University
MFF UK
Malostranske nam. 25

118 00 Praha 1
CZECH REPUBLIC

Prof.Dr. Hans Jürgen Prömel
Forschungsinstitut für
Diskrete Mathematik
Universität Bonn
Nassestr. 2

D-53113 Bonn

Prof.Dr. Gert Sabidussi
Dept. of Mathematics and Statistics
University of Montreal
C. P. 6128, Succ. A

Montreal , P. Q. H3C 3J7
CANADA

Prof.Dr. Bruce Richter
Department of Mathematics and
Statistics
Carleton University
710 Dunton Tower

Ottawa , Ont. K1S 5B6
CANADA

Dr. Paul D. Seymour
Bellcore
445, South Street

Morristown , NJ 07962-1910
USA

Prof.Dr. Gerhard Ringel
Dept. of Mathematics
University of California

Santa Cruz , CA 95064
USA

Prof.Dr. Vera Sos
Mathematical Institute of the
Hungarian Academy of Sciences
P.O. Box 127
Realtanoda u. 13-15

H-1364 Budapest

Prof.Dr. Neil Robertson
Department of Mathematics
Ohio State University
231 West 18th Avenue

Columbus , OH 43210-1174
USA

Prof.Dr. Michael Stiebitz
Institut für Mathematik
Technische Universität Ilmenau
Postfach 327

D-98684 Ilmenau

Prof.Dr. Bruce L. Rotschild
Dept. of Mathematics
U.C.L.A.

Los Angeles, CA 90024
USA

Prof.Dr. Robin Thomas
School of Mathematics
Georgia Institute of Technology

Atlanta , GA 30332
USA

Prof.Dr. Carsten Thomassen
Matematisk Institut
Danmarks Tekniske Højskole
Bygning 303

DK-2800 Lyngby

Prof.Dr. Bjarne Toft
Matematisk Institut
Odense Universitet
Campusvej 55

DK-5230 Odense M

Prof.Dr. Helge Tverberg
Institute of Mathematics
University of Bergen
Allegt 53 - 55

N-5007 Bergen

Prof.Dr. Heinz-Jürgen Voß
Institut für Algebra
Technische Universität Dresden

D-01062 Dresden

Prof.Dr. Dan H. Younger
Department of Combinatorics and
Optimization
University of Waterloo

Waterloo . Ont. N2L 3G1
CANADA