Graph Theory 2008 at Sandbjerg Manor

August 17-23, 2008

Drawing by J. Nešetřil

Program and Abstracts

Preface

The Danish graph theory community (represented by Lars Døvling Andersen, Jørgen Bang-Jensen, Leif Kjær Jørgensen, Carsten Thomassen, Bjarne Toft, Preben Dahl Vestergaard) arranges the meeting GRAPH THEORY 2008 AT SANDBJERG MANOR, August 17-23, 2008. The meeting focuses on all aspects of graph theory. During the meeting we celebrate Carsten Thomassen's 60th birthday (Aug. 22, 2008).

We are grateful for the support provided by

The Danish Agency for Science, Technology and Innovation,

The Carlsberg Foundation,

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The Department of Mathematics and Computer Science
at the University of Southern Denmark.

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Program Overview

Sunday August 17

Recommended day of arrival. No dinner, but sandwiches available in the evening.

Monday August 18

08:00-09:00 Breakfast

09:00-12:00 Plenary lectures

12:00-13:00 Lunch

15:00-18:00 Parallel lectures

18:00-19:00 Dinner

19:30-21:30 Lecture and Problem session

Tuesday August 19

08:00-09:00 Breakfast

09:00-12:00 Plenary lectures

12:00-13:00 Lunch

15:00-18:00 Parallel lectures

18:00-19:00 Dinner

19:30-21:30 Plenary short lectures

Wednesday August 20

08:00-09:00 Breakfast

09:00-12:00 Plenary lectures

12:00-13:00 Lunch

13:00-18:00 Excursion

18:00-19:00 Dinner

Thursday August 21

08:00-09:00 Breakfast

09:00-12:00 Plenary lectures

12:00-13:00 Lunch

15:00-18:00 Parallel lectures

19:00-21:00 Conference dinner

Friday August 22

08:00-09:00 Breakfast

09:30-10:00 Carsten Thomassen plenary lecture

10:00-12:00 Plenary lectures

12:00-13:00 Lunch

15:00-18:00 Plenary lectures

18:00-19:00 Dinner

20:00-??:?? Birthday get together

Saturday August 23

08:00-09:00 Breakfast

09:00-12:00 Plenary lectures

12:00-13:00 Lunch

Recommended day of departure

Carsten Thomassen elaborating on Hajós' Conjecture.

Sexagesimal[1]

To be sixty years old, to be solemn and sage
And a fount of the wisdom that mellows with age
Esteemed by the old and revered by the young –
And to sit at a feast where ones praises are sung.

To be sixty years old, to look over ones field
And survey the knowledge oneself has revealed
In papers well-structured for learning and gain
And students and friends like pearls in a chain.

How good to be sixty! Yet each may aspire
Diamond Jubilee joys for himself to acquire
What happens to Carsten can happen to thee!
I try to forget it happend to me.

[1] After *Blanche Descartes*.

Talks: Titles and Abstracts[2]

Michael O. Albertson, Smith College, USA

The Chromatic Number and the Crossing Number

This talk will give a highlights tour of recent results and open questions that relate the chromatic number and crossing number of a graph. For instance, given a drawing of a graph G, two crossings are said to be *dependent* if they are incident with the same vertex. A set of crossings is *independent* if no two are dependent. We conjecture that if G is a graph that has a drawing all of whose crossings are independent, then $\chi(G) \leq 5$. This conjecture is true when $\mathrm{cr}(G) \leq 3$. We do know that if all crossings are independent, then $\chi(G) \leq 6$, and the independence ratio of G is at least $\frac{3}{16}$.

Robert E.L. Aldred, University of Otago, New Zealand

(joint work with Carsten Thomassen)

Bounding the maximum number of cycles
in a graph with p vertices and q edges

Let G be a connected graph with p vertices and q edges and define the parameter $r = q - p + 1$. Denote by $\Psi(r)$ the maximum number of cycles in such a graph. In 1981 it was noted by Entringer and Slater that the dimension of the cycle space of such a graph is known to be 2^r and consequently, $\Psi(r) \leq 2^r - 1$. In the same paper, the Möbius ladders were used to show $\Psi(r) \geq 2^{r-1} + r^2 - 3r + 3$. At the time it was conjectured that the true value of $\Psi(r)$ should be closer to the latter bound. We discuss these bounds and some recent progress in the general case along with an effective resolution of the conjecture for planar graphs.

[2]Ordered alphabetically according to the surnames of the speakers.

Dan Archdeacon, University of Vermont

Superthrackles

We give a complete characterization of graphs that can be drawn in the plane such that every pair of edges, adjacent or non-adjacent, cross exactly once.

Tinaz Ekim Aşici, Boğaziçi University, Turkey

Generalized Colorings with Applications to some Problems in Robotics

We study the problem where a robot has to pick up items of different sizes which are stored along a corridor. A natural requirement is that the items have to be collected in decreasing order of their sizes. We deal with various systems according to the location of the Entry/Exit station where the robot unloads the collected items after each trip along the corridor. We show that each of these systems can be modeled as a generalized coloring problem in permutation graphs. More precisely, we will be dealing with the problems called Minimum Split Coloring and Minimum Cocoloring. We discuss related complexity issues. Besides, we observe that some systems cannot be modeled in terms of graphs but only in terms of permutations. Some open questions related to the last-mentioned problems will be discussed.

János Barát, University of Szeged, Hungary

Islands

Let an $n \times m$ rectangular board be given. We associate a real number (altitude) to each cell, that is a 1×1 square. Two different cells are neighbors if they have at least a point in common. A rectangular subtable S is called an island if the altitude of each cell in S is greater than the altitude of the neighbors of S. The motivation is obvious, when we imagine a vast rainfall over the board, the above defined islands will be formed. A basic question is the following: What is the maximum number of different islands?

In the talk, we will show how Carsten is connected to this problem. We will give a solution using some graph theory. If time permits, we will describe several generalizations and open problems.

Thomas Böhme, TU Ilmenau, Germany

(joint work with Jens Schreyer and Patrick Bauermann)

On applications of graph theory in game theory

An n player game Γ in strategic form consist of a set $I = \{1, \dots, n\}$ of players, and for each player $i \in I$ a finite set A^i of actions and a payoff function $u^i : A^1 \times \cdots \times A^n$. We define the graph $G(\Gamma)$ to be the graph with vertex set I. Two vertices (players) i and j are connected by a directed edge from i to j if and only if player i's action can influence the payoff of player j. We consider a repeated play of Γ at discrete time intervalls $t = 1, 2, \dots$. Initially, each player knows her set of actions but nothing else about the game. After the k'th play each player observes her realized action and the respective payoff but nothing about the other players' play. The main result is that the players can learn to play a pure Nash equilibrium, provided Γ has a pure Nash equilibrium, if the graph $G(\Gamma)$ is strongly connected.

Adrian Bondy, Université Claude-Bernard Lyon 1, France

Paths and Cycles in Digraphs

Carsten Thomassen has made significant and beautiful contributions to many areas of graph theory. We shall survey just one small aspect of his work, namely that on paths and cycles in digraphs. We shall also present a number of open problems and conjectures on the topic, and discuss recent progress on some of them.

Oleg Borodin, Sobolev Institute of Mathematics, Russia

Recent results on the planar 3-coloring

This is a summary of results on the 3-coloring of planar graphs obtained recently with the participation of people from Novosibirsk.

Debra Boutin, Hamilton College, USA

The Cost of 2-Distinguishing

A graph is said to be 2-*distinguishable* if there is a labeling of the vertices with two labels so that only the trivial automorphism preserves the vertex labels. Define the 2-*distinguishing cost* of G, denoted $\rho(G)$, to be the minimum size of a label class in such a labeling. A *determining set* of a graph is a subset of its vertices with the property that each automorphism of the graph is uniquely determined by its action on the set. For a 2-distinguishable graph a determining set can be an elegant first approximation of a label class. This talk will introduce the 2-distinguishing cost, then define and use determining sets to find good bounds on $\rho(Q_n)$ and $\rho(K_3^n)$. We will see that both are $\Theta(\log n)$.

Stephan Brandt, TU Ilmenau, Germany

(joint work with Elizabeth Ribe-Baumann)

Dense graphs with large odd girth

Generalizing a result from Häggkvist and Jin for the case $k = 3$, it can be shown that every graph of order n with odd girth at least $2k+1$ and minimum degree $\delta \geq 3n/4k$ is either homomorphic with C_{2k+1} or can be obtained from the Möbius ladder with $2k$ spokes by vertex duplications. The key tools used in our observations are simple characteristics of maximal odd girth $2k + 1$ graphs.

Kathie Cameron, Wilfrid Laurier University, Canada

(joint work with Jack Edmonds)

Coflow, Covering Vertices by Directed Circuits, and a Lower Bound on the Stability Number of a Graph

Let G be a digraph, and for each edge e of G, let $d(e)$ be a non-negative integer. The capacity, $d(C)$, of a dicircuit C means the sum of the $d(e)$'s of the edges in C. A version of the Coflow Theorem (1982) says:

Coflow Theorem. *The maximum size of a subset S of vertices of digraph G such that each dicircuit C of G contains at most $d(C)$ members of S equals the minimum of the sum of the capacities of any subset H of dicircuits of G plus the number of vertices of G which are not in a dicircuit of H.*

When we proved the Coflow Theorem, we hoped to prove the following conjecture made by Gallai in 1963:

Gallai's Conjecture. *For any digraph G such that each edge and each vertex is in a dicircuit, the maximum number of vertices in G no two of which are joined by an edge is at least as big as the minimum number of dicircuits which together cover all the vertices.*

However, we were missing the following:

Lemma. *For any digraph G such that each edge and each vertex is in a dicircuit, G contains a set F of edges such that $G - F$ is acyclic and every edge of G is in some dicircuit which contains exactly one edge of F.*

We recently learned that Knuth proved this lemma in 1974. The Coflow Theorem together with Knuth's Lemma provides a proof of Gallai's Conjecture different from that recently published by Bessy and Thomassé.

Carl Johan Casselgren, Umeå Universitet, Sweden

(joint work with A.S. Asratian, J. Vandenbussche and D.B. West)

Interval edge colorings of (a, b)-biregular bipartite graphs

An edge coloring of a graph G is called an interval coloring if the colors on the edges incident with each vertex of G are distinct and form an interval of integers. An (a, b)-biregular bigraph is a bipartite graph in which each vertex of one part has degree a and each vertex of the other part has degree b. We survey recent results on interval colorings of general (a, b)- biregular bigraphs and pay particular attention to the case of $(3, 4)$-biregular bigraphs. By a well-known conjecture of Toft, every $(3, 4)$-biregular bigraph has an interval coloring with 6 colors. We will discuss a new sufficient condition for $(3, 4)$-biregular bigraphs to admit interval colorings: If such a graph G has a spanning subgraph whose components are paths with endpoints at 3-valent vertices and lengths in $\{2, 4, 6, 8\}$, then G has an interval coloring.

Gek Ling Chia, University Malaya, Malaysia

(joint work with Carsten Thomassen)

Grinberg's Criterion on Non-Planar Graphs

Robertson (1968) and independently, Bondy (1972) proved that the generalized Petersen graph P(n, 2) is hamiltonian if $n \equiv 5 \pmod 6$ while Thomason (1982) proved that it has precisely three hamiltonian cycles if $n \equiv 3 \pmod 6$. Here we give a unified proof (which is easier) of these results using Grinberg's theorem.

Maria Chudnovsky, Columbia University, USA

The structure of bullfree graphs

The bull is a graph consisting of a triangle and two disjoint pendant edges. Obvious examples of bullfree graphs are graphs with no triangle, or graphs with no stable set of size three. But there are others (for examples substituting one bullfree graph into another produces another bullfree graphs). It turns out, however, that one can explicitly describe all bullfree graphs that cannon be constructed from smaller ones by substitutions. In this talk we will discuss this construction. We will also mention the connection with the Erdős-Hajnal conjecture.

Reinhard Diestel, Universität Hamburg, Germany

$\pi_1(|G|)$, earrings, and limits of free groups

We characterize the fundamental group of a locally finite graph G with ends, by embedding it canonically as a subgroup in the inverse limit of the free groups $\pi_1(G')$ with $G' \subset G$ finite. As an intermediate step, we characterize $\pi_1(|G|)$ combinatorially as a group of infinite words.

This is joint work with Philipp Sprüssel. The paper, and the application to graph homology that prompted us to study the fundamental group, can be found at

`http://www.math.uni-hamburg.de/home/diestel/papers/Homotopy.pdf`
`http://www.math.uni-hamburg.de/home/diestel/papers/Homology.pdf`

Jack Edmonds, Université Pierre et Marie Curie, France

Euler Complexes

We present a class of instances of the existence of a second object of a specified type, in fact, of an even number of objects of a specified type, which generalizes the existence of an equilibrium for bimatrix games. The proof is an abstract generalization of the Lemke-Howson algorithm for finding an equilibrium of a bimatrix game.

Herbert Fleischner, Austrian Academy of Sciences, Austria

Carsten's contributions to the Hamiltonian theme

In this talk, I review some of Carsten's results on hamiltonian graphs, including hypohamiltonian graphs and uniquely hamiltonian graphs.

John Gimbel, University of Alaska Fairbanks, USA

(joint work with Tinaz Ekim Aşici)

Defective Cocolorings of Graphs

Given an integer k, a k-defective coloring is a partition of the vertex set where each part induces a graph with a maximum degree of at most k. A cocoloring is a partition where each part induces a complete or empty graph. The two concepts are the subject of several papers. In this talk we introduce a fusion of the two ideas. A k-defective cocoloring is a partition of the vertex set where each part induces a graph with maximum degree at most k or induces in the complement of such a graph. We discuss some preliminary notions related to this parameter.

Ronald J. Gould, Emory University, USA

Distributing vertices on hamiltonian cycles

Let G be a graph of order n and $3 \leq t \leq \frac{n}{4}$ be an integer. Recently, Kaneko and Yoshimoto provided a sharp $\delta(G)$ condition such that for any set X of t vertices, G contains a hamiltonian cycle H so that the distance along H between any two vertices of X is at least $n/2t$. In this paper, minimum degree and connectivity conditions are determined such that for any graph G of sufficiently large order n and for any set of t vertices $X \subseteq V(G)$, there is a hamiltonian cycle H so that the distance along H between any two consecutive vertices of X is approximately $\frac{n}{t}$. Furthermore, we determine the δ threshold for any t chosen vertices to be on a hamiltonian cycle H in a prescribed order, with approximately predetermined distances along H between consecutive chosen vertices.

Gregory Gutin, Royal Holloway, University of London, UK

Out-branchings with Extremal Number of Leaves

An out-tree T in a digraph D is subgraph of D which is an orientation of a tree that has only one vertex of in-degree 0 (root). A vertex of T is a leaf if it has out-degree 0. A spanning out-tree is called an out-branching. We'll overview some recent algorithmic and theoretical results on out-branchings with minimum and maximum number of leaves.

Ervin Győri, Hungarian Academy of Sciences, Hungary

On 2-factors in graphs

We plan to present sufficient degree conditions for graphs to have 2-factors consisting of exactly k cycles. In some cases, we strengthen the statement by having prescribed edges, in some cases we weaken the degree condition by assuming Hamiltonicity.

Roland Häggkvist, Umeå Universitet, Sweden

Some facts about (a, b)-biregular bigraphs and path factors

An (a, b)-biregular bigraph (or an (a, b)-graph) is a bipartite graph where the vertices in one part have degree a and all vertices in the other part have degree b.

In addition to the following facts that shall be plugged:

- Every 2-edge-connected $(3, 4)$-graph of girth 6 has a $P_{4,3}$-decomposition, where a $P_{k,k-1}$ is a path of length $2k - 2$ with k vertices in the first part and $k - 1$ vertices in the second part,

- there exists an infinite number of 2-edge-connected $(3, 4)$-graphs where every $\{P_{2,1}, P_{3,2}, \ldots\}$ factor is a $\{P_{3,2}, P_{5,4}\}$-factor, and

- a 2-edge-connected $(3, 4)$-graph on $7k$ vertices contains a 2-regular subgraph H on $6k$ vertices.

I shall discuss the following observation:

- Every $(b, b + 1)$-graph has a $\{P_{2,1}, P_{3,2}, \ldots\}$-factor if and only if $b \geq 1$ and it has a $\{P_{1,0}, P_{2,1}, P_{3,2}, \ldots\}$-factor.

Pavol Hell, Simon Fraser University, Canada

Graphs and Polymorphisms

Polymorphisms are of interest in algebra and logic, and they are conjectured to be a universal tool for proving tractability of constraint satisfaction problems. I will illustrate their appeal and usefulness in graph theory, by giving a guided tour of some new and some well known graph classes defined by the existence of basic polymorphisms.

Jing Huang, University of Victoria, Canada

Partitions and bichromatic numbers of graphs

For a pair of integers $k, \ell \geq 0$, a graph $G = (V, E)$ is (k, ℓ)-colourable if V can be partitioned into $k + \ell$ (possibly empty) subsets $I_1, \ldots, I_k, C_1, \ldots, C_\ell$ such that each I_i induces an independent set and each C_j induces a clique in G. The (k, ℓ)-colourability, which generalizes both colouring and clique covering, best approximates the hereditary property of graphs. The bichromatic number $\chi^b(G)$ of G is the least integer r such that for all k, ℓ with $k + \ell = r$, G is (k, ℓ)-colourable. It is easy to see that $\chi^b(G)$ is bounded above by $\chi(G) + \theta(G) - 1$ where $\chi(G)$ and $\theta(G)$ are respectively the chromatic number and the clique covering number of G. Here we characterize all graphs G for which the upper bound is attained, i.e., $\chi^b(G) = \chi(G) + \theta(G) - 1$. It turns out that these graphs are all cographs and they are critical in the sense that a cograph H is not (k, ℓ)-colourable if and only if H contains an induced subgraph G with $\chi(G) = k + 1$, $\chi(G) = \ell + 1$ and $\chi^b(G) = k + \ell + 1$.

Joan Hutchinson, Macalester College, USA

(joint work with M.O. Albertson)

Extending precolorings to list-colorings

Answering some questions of C. Thomassen, results are known on extending precolorings to colorings of an entire graph. Similarly list-colorings are sought that extend pre-list-colorings. Using recent work of A.Pruchnewski and M.Voigt we consider results in which precolorings are extended to list-colorings of the entire graph for planar graphs, bipartite graphs, K_4- and K_5-minor-free graphs.

Tommy R. Jensen, Universität Klagenfurt, Austria

Circuit Double Covers and locally Tait colourings

It has been suggested that every 2-edge-connected graph may have its edges double covered by circuits, even when any one circuit of the graph has been fixed in advance. This open problem reduces to cubic graphs. For those cubic graphs that allow Tait colourings, i.e. proper 3-edge-colourings, it is easy to solve. The talk will describe a stronger variation of this problem. In the case of a fixed Hamilton circuit our new version can be solved by applying proper edge colourings that may use more than three colours globally, yet locally they are similar to Tait colourings. Colourings of this type have the advantage that they occur also in many cubic graphs that are not Tait colourable, possibly even in all cubic graphs.

Tibor Jordán, Eötvös Loránd University, Hungary

Graph theoretical characterization of uniquely localizable networks

Suppose that V is a set of nodes in the plane (or in three dimensions) and we are given the distance between some pairs of nodes in V. When does this distance information uniquely determine the location of all nodes, up to congruence?

When the nodes are in 'general position' , unique localizability depends only on the graph of the known distances. We shall discuss a few recent results and open problems related to this question and show how graph and matroid theoretical methods can be used to attack different variations of this problem.

Ken-ichi Kawarabayashi, The National Institute of Informatics, Japan

From Carsten's Proofs/Results to Hadwiger's Conjecture

Around 15 years ago, Carsten Thomassen proved that there are only finitely many 6-color-critical graphs on a fixed surface. The result itself is very deep, but the methods are also useful.

In this talk, we shall show how the CT's methods can be used to prove the following theorems concerning Hadwiger's conjecture (which says that every graph with no K_t-minor is $(t-1)$-colorable).

1. Every minimal counterexample to Hadwiger's conjecture has at most $f(t)$ vertices for some function f of t.

2. There is a polynomial time (actually, we believe an $O(n^2)$ time !) algorithm to decide Hadwiger's conjecture for fixed t.

In addition, we shall discuss the following topics:

1. Does every t-colorable graph with no K_t-minor have exponentially many colorings?

2. Additive approximation algorithm for list-coloring graphs with no K_t-minor.

3. t-colorability of graphs with no K_{t+1}-minor.

All of these topics are motivated by CT's work on coloring graphs in a fixed surface.

Martin Kochol

A negative solution of the edge-coloring conjecture of Grünbaum

An embedding of a graph in a surface is called polyhedral if its dual has no multiple edges and loops. A conjecture of Grünbaum, presented in 1968, states that each 3-regular graph with a polyhedral embedding in an orientable surface has a 3-edge-coloring. This statements holds true for the sphere, because by Tait, the Four Color theorem is equivalent with the statement that each 2-edge-connected 3-regular planar graph has a 3-edge-coloring. Thus the Grünbaum's conjecture aims to generalize the Four Color Theorem for any orientable surface. We present a negative solution of this conjecture, showing that for each orientable surface of genus at least 5, there exists a 3-regular non 3-edge-colorable graph with a polyhedral embedding in it.

Alexandr V. Kostochka, University of Illinois at Urbana-Champaign, USA

(joint work with M. Kumbhat and V. Rödl)

Coloring simple uniform hypergraphs of small size

A hypergraph is *simple* if it has no 2-cycles, i.e., no two distinct edges of the hypergraph have more one vertex in common. Let $m^*(r,k)$ denote the fewest edges that might have a simple r-uniform non-k-colorable hypergraph. Erdős and Lovász proved that

$$\frac{k^{2(r-2)}}{16r(r-1)^2} \le m^*(r,k) \le 1600r^4k^{2(r+1)}.$$

Szabó improved the lower bound by a factor of $r^{2-\epsilon}$ for large r. We improve both, upper and lower bound for large r (in comparison to k and ϵ) to

$$k^r/r^\epsilon \le m^*(r,k) \le c \cdot (r \ln k)^2 k^{2r}.$$

The bounds generalize to b-simple hypergraphs, i.e. hypergraphs in which no two distinct edges share more than b vertices. We also give a new random construction of r-uniform non-k-colorable hypergraphs of arbitrary girth with maximum degree at most $\lceil r\, k^{r-1} \ln k \rceil$.

Jan Kratochvíl, Charles University, Czech Republic

(joint work with Petr Golovach)

Generalized domination in special graph classes

We investigate the interplay of polynomial solvability and warranty of unique solution of the problem under consideration, in the setting of generalized domination.

Given sets σ, ρ of nonnegative integers (as parameters of the problem), a set S of vertices of a graph G is called (σ, ρ)-*dominating* if the number of S-neighbors of any vertex of S (of $V \setminus S$) is an element of σ (ρ, respectively). This notion was introduced by Telle and has been investigated by Telle, Proskurowski, Heggernes, Miller, etc. In particular, for any pair of finite nonempty sets σ, ρ (such that $0 \notin \rho$), already deciding the existence of a (σ, ρ)-dominating set in an input graph is NP-complete. Polynomial/NP-completeness dichotomy results for restricting the input graphs to be chordal (or k-degenerate) were obtained by Golovach and Kratochvil. They relate to the concept of ambivalence in the following sense.

Given a graph class M, the pair (σ, ρ) is called *ambivalent for* M if there exists a graph $G \in M$ with at least two different (σ, ρ)-dominating sets; otherwise it is *non-ambivalent for* M. For chordal graphs, the existence of a (σ, ρ)-dominating set can be decided in polynomial time when the pair (σ, ρ) is non-ambivalent for chordal graphs, and the problem is NP-complete otherwise. Similarly for k-degenerate graphs (for any $k \geq 2$).

The last part of the talk will deal with planar graphs, where we are not able to fully characterize the computational complexity, nor the connection to ambivalence. We believe that this leads to interesting open problems.

Matthias Kriesell, Mathematisches Seminar der Universität Hamburg, Germany

Packing Steiner Trees

An A-*tree* in a graph is a subgraph which covers A, and an A-*tree-packing* is a family of edge disjoint A-trees. Large A-tree-packings indicate good connectivity properties of A. In real networks, they yield good fault tolerance or transmission bandwidth among a selected set of vulnerable or service providing nodes, respectively, as in backbone– or hub-&-spoke–architectures. Therefore, it is desirable to find good solutions for the corresponding packing problem. The talk surveys the efforts put into this over the past years.

Daniela Kühn, Birmingham University, UK

(joint work with Peter Keevash, Luke Kelly, Deryk Osthus and Andrew Treglown)

Hamilton cycles in directed graphs

It is unlikely that there exists a satisfactory characterization of all those graphs which contain a Hamilton cycle, so much work has been done to find simple sufficient conditions. The most famous result in this direction is Dirac's theorem which gives a minimum degree condition for the existence of a Hamilton cycle.

Surprisingly, the corresponding problems are much more difficult for directed graphs and oriented graphs (oriented graphs are directed graphs with at most one edge between each pair of vertices). In my talk, I will discuss (i) an analogue of Dirac's theorem for oriented graphs and (ii) an approximate solution of a conjecture of Nash-Williams which would give a characterization of all degree sequences forcing a Hamilton cycle in a directed graph.

Hao Li, Université Paris-Sud, France

TBA

Vadim V. Lozin, University of Warwick, UK

Boundary properties of graphs

The notion of a boundary graph property is a relaxation of that of a minimal property. Several fundamental results in graph theory have been obtained in terms of identifying minimal properties. For instance, Robertson and Seymour showed that there is a unique minimal minor-closed property with unbounded tree-width (the planar graphs), while Balogh, Bollobás and Weinreich identified nine minimal hereditary properties with the factorial speed of growth. However, there are situations where the notion of minimal property is not applicable. A typical example of this type is given by graphs of large girth. It is know that for each particular value of k, the graphs of girth at least k are of unbounded tree-, clique- or rank-width and their speed of growth is superfactorial, while the 'limit' property of this sequence (i.e., acyclic graphs) has bounded tree-, clique- and rank-width and their speed of growth is factorial. To overcome this difficulty, we introduce the notion of boundary properties of graphs and identify some of them with respect to various graph problems.

Gary MacGillivray, University of Victoria, Canada

Injective homomorphisms of directed graphs

A homomorphism from a digraph D to a digraph H is called *injective* if it is injective on the in-neighbourhood of each vertex. Complexity results for injective homomorphisms of irreflexive digraphs D are considered in the case when the target digraph H is reflexive, and in the case where the target graph H is irreflexive. A dichotomy theorem is obtained in the case where H is reflexive, whereas a such a theorem in the case where H is irreflexive would imply one for all digraph homomorphism problems. The complexity of the related *injective oriented chromatic number* problems (the minimum n for which a digraph D admits an injective homomorphism to a digraph on n vertices – defined together with A. Raspaud) is also discussed.

Wolfgang Mader, Universität Hannover, Germany

Openly disjoint circuits through a vertex

Almost 60/2 years ago, Carsten Thomassen constructed, for every positive integer r, finite digraphs of minimum outdegree and minimum indegree at least r without a vertex y contained in 3 circuits which have pairwise exactly y in common. We study what happens, if we add further conditions as high connectivity or regularity.

Brendan McKay, Australian National University, Australia

Recursive generation of 5-regular planar graphs

We describe for the first time how the 5-regular simple planar graphs can all be obtained from a simple family of starting graphs by repeatedly applying a few expansion operations. The proof uses an innovative amalgam of theory and computation. By incorporating the recursion into the canonical construction path method of isomorph rejection, a generator of non-isomorphic 5-regular planar graphs is obtained with time complexity $O(n^2)$ per isomorphism class.

Bojan Mohar, Simon Fraser University, Canada

(joint work with Simon Špacapan)

Coloring parameters and genus

We overview several coloring parameters whose value is bounded on graphs of bounded (Euler) genus. These include the usual chromatic number, the acyclic, the star and the degenerate chromatic number, and some of their relatives. We determine their dependence on the genus. The probabilistic method is used in proving both upper and lower bounds.

Jaroslav Nešetřil, Charles University, Czech Republic

(joint work with Patrice Ossona de Mendez)

On nowhere dense and somewhere dense - a graph trichotomy

Motivated by structural decompositions and other asymptotic properties of graphs we define the notions in the title and show the wide spectrum of examples of nowhere dense graphs. This has several algorithmic consequences and it generalizes and improves earlier results.

Deryk Osthus, Birmingham University, UK

(joint work with Luke Kelly and Daniela Kühn)

Cycles of given length in oriented graphs

The Caccetta-Häggkvist conjecture would determine the minimum outdegree which forces a cycle of length at most k in an oriented graph. We study the related question of which minimum out- and indegree forces a cycle of length exactly k in an oriented graph. We answer this question whenever k is not a multiple of 3 and propose a conjecture for the other cases.

Shariefuddin Pirzada, University of Kashmir, India

Some Lists in Bipartite Multi-Hypertournaments

Given non-negative integers m,n,h and k with $m \geq h \geq 1$ and $n \geq k \geq 1$, an $[h, k]$-bipartitie multi hypertournament (or briefly $[h, k]$-BMHT) on $m+n$ vertices is a triple (U, V, A), where U and V are two sets of vertices with $|U| = m$ and $|V| = n$ and A is a set of $(h + k)$-tuples of vertices, called arcs with exactly h vertices from U and exactly k vertices from V, such that any $h + k$ subset $U_1 U V_1$ of UUV, A contains at least one and at most $(h + k)!$ $(h + k)$-tuples whose entries belong to $U_1 U V_1$. If A is a set of $(h + k)$-tuples of vertices with at least one and at most k vertices from V such that A contains at least one and at most $(h + k)!$ $(h + k)$-tuples,then the bipartite multi hypertournament (or briefly (h, k)-BMHT). We obtain necessary and sufficient conditions for a pair of non-negative integers in non-decreasing order to be losing score lists and score lists of $[h, k]$-BMHT and (h, K)-BHMT.

Michael D. Plummer, Vanderbilt University, USA

(joint work with Ken-ichi Kawarabayashi)

Bounding the size of equimatchable graphs of fixed genus

A graph G is said to be *equimatchable* if every matching in G extends to (i.e., is a subset of) a maximum matching in G. In a 2003 paper, Kawarabayashi, Plummer and Saito showed that there are only a finite number of 3-connected equimatchable planar graphs. In the present paper, this result is extended by showing that in a surface of any fixed genus (orientable or non-orientable), there are only a finite number of 3-connected equimatchable graphs having a minimal embedding of representativity at least three. The proof makes use of the Gallai-Edmonds decomposition theorem for matchings.

André Raspaud, Université de Bordeaux I, France

Star coloring of sparse graphs

A proper coloring of the vertices of a graph is called a *star coloring* if the union of every two color classes induce a star forest. The star chromatic number $\chi_s(G)$ is the smallest number of colors required to obtain a star coloring of G. In this talk we will present bounds of $\chi_s(G)$ for sparse graphs.

Dieter Rautenbach, TU Ilmenau, Germany

(joint work with Stephan Brandt, Jozef Miskuf and Friedrich Regen)

Edge-Injective and Edge-Surjective Vertex Labellings

For a graph $G = (V, E)$ we consider vertex-k-labellings $f : V \to \{1, 2, \ldots, k\}$ for which the induced edge weighting $w : E \to \{2, 3, \ldots, 2k\}$ with $w(uv) = f(u) + f(v)$ is injective or surjective or both.

We study the relation between these labellings and the number theoretic notions of an additive basis and a Sidon set, present a new construction for a so-called restricted additive basis and derive the corresponding consequences for the labellings.

We prove that a tree of order n and maximum degree Δ has a vertex-k-labelling f for which w is bijective if and only if $\Delta \leq k = n/2$. Using this result we prove a recent conjecture of Ivančo and Jendrol' concerning edge-irregular total labellings for graphs that are sparse enough.

Bruce Reed, McGill University, Canada

Parity Minors and Parity Routing

We discuss extensions of the seminal results of the graph minor project of Robertson and Seymour to 'odd minors'. We discuss applications both to problems about packing paths and cycles of specified parities, and to Hadwiger's conjecture. Early work in this area, which motivated many of these results is due to Carsten Thomassen.

Bruce Richter, University of Waterloo, Canada

Theorems of MacLane and Whitney for Graph-Like Spaces

Abstract not yet available.

Neil Robertson, The Ohio State University, USA

TBA

Gert Sabidussi, McGill and U. de Montréal, Canada

(joint work with Herbert Fleischner and Vladimir Sarvanov)

Independent Sets in 4-Regular Hamiltonian Graphs

In the early 90s, Du,Hsu and Hwang raised the question whether 4-regular hamiltonian graphs whose inner cycles are triangles ("cycle-plus-triangles graphs") contain independent sets of size at least n/3, where n is the order of the graph. A well-known result, conjectured by Erdös and proved by Fleischner and Stiebitz, provides an affirmative answer in the stronger sense that cycle-plus-triangles graphs are 3-colorable. This result cannot be generalized to "smooth" 4-regular hamiltonian graphs (i.e. whose inner cycles - like triangles - are non-selfintersecting): it has been shown that for such graphs 3-colorability is NP-complete. This left open the extension to smooth 4-regular hamiltonian graphs of the original question of Du, Hsu and Hwang concerning independent sets. We show that for these graphs both the Maximum Independent Set Problem (MIS) and the Large Independent Set Problem (existence of an independent set of size at least n/3) are NP-complete. As an auxiliary result we prove that MIS is NP-complete also for 3-regular hamiltonian graphs, indeed even for planar hamiltonian 3-regular graphs.

Horst Sachs, TU Ilmenau, Germany

(joint work with Peter John)

Spectral theory of n-fold periodic graphs with applications to toroidal 6-cages, $(3,6)$-cages, and $(2,6)$-cages

Toroidal 6-cages (i.e., hexagonal tesselations of the torus, in a chemical context also called toroidal fullerenes) are used as prototypes for outlining a general spectral theory of n-dimensional toroidal graphs derived from some locally finite n-fold periodic graph.

The results are used to calculate explicitly spectra and orthonormal eigenvector systems of toroidal 6-cages, $(3,6)$-cages and $(2,6)$-cages (a $(q,6)$-cage, where $q \in \{2,3,4,5\}$, is a two-connected cubic plane graph that has only q-gons and hexagons as its faces; the graph of an ordinary fullerene is a $(5,6)$-cage).

Ingo Schiermeyer, TU Freiberg, Germany

(joint work with Stephan Matos Camacho and Zsolt Tuza)

Approximation algorithms for the minimum rainbow subgraph problem

Our research was motivated by the pure parsimony haplotyping problem: Given a set $\mathcal{G}$ of genotypes, the haplotyping problem consists in finding a set $\mathcal{H}$ of haplotypes that explains $\mathcal{G}$. In the pure parsimony haplotyping problem (PPH) we are interested in finding a set $\mathcal{H}$ of smallest possible cardinality.

The pure parsimony haplotyping problem can be described as a graph colouring problem as follows:

The minimum rainbow subgraph problem

Given a graph G, whose edges are coloured with p colours. Find a subgraph $F \subseteq G$ of G of minimum order with $|E(F)| = p$ such that each colour occurs exactly once.

In this talk we will present polynomial time approximtaion algorithms for the minimum rainbow subgraph problem:

- Applying the greedy algorithm we obtain an approximation algorithm with an approximation ratio of $\mathbf{\Delta(G)}$ for graphs with maximum degree $\Delta(G)$.

- Based on matching techniques we present an approximation algorithm with an approximation ratio of $\mathbf{\frac{5}{3}}$ for graphs with maximum degree 2.

Paul Seymour, Princeton University, USA

(joint work with Maria Chudnovsky and Bruce Reed)

The densest graphs with no $K_{2,t}$ minor

For a graph H and an integer n, let $e(H, n)$ be the maximum number of edges of an n-vertex simple graph with no minor isomorphic to H. For all choices of H, it is known that $e(H, n)$ is at most linear in n, but finding it exactly is much more difficult.

For instance, it is easy to see that for $n \geq t - 2$,

$$e(K_t, n) \geq (t-2)n - (t-1)(t-2)/2.$$

Mader showed that equality holds for $t \leq 7$, but *not* for $t = 8$ and larger; and Kostochka and Thomason showed that $e(K_t, n)/n = O(t\sqrt{(}\log t))$ for t large.

For other graphs H, the function $e(H, n)$ has not been studied so exhaustively. The answer is easy when $H = K_{1,t}$, but challenging even when $H = K_{2,t}$. The natural conjecture is that $e(K_{2,t}, n) \leq (n-1)(t+1)/2$, for then equality would hold at least whenever t divides $n-1$; and in 2003 Myers proved this for all $t \geq 10^{29}$. In joint work with Maria Chudnovsky and Bruce Reed, we have proved this for all t. We sketch the proof and related topics.

Matěj Stehlík, Charles University, Czech Republic

(joint work with Daniel Král)

The chromatic number of triangle-free graphs on the double torus

The classical theorem of Grötzsch asserts that every triangle-free planar graph is 3-colourable. Triangle-free graphs embeddable on the torus are 4-colourable, as was shown by Kronk and White. Gimbel and Thomassen asked whether triangle-free graphs on the double torus are also 4-colourable. This question was recently settled in the affirmative; here we present the proof of this result.

Michael Stiebitz, TU Ilmenau, Germany

Edge Colouring of Multigraphs

There are two trivial lower bounds for the *chromatic index* $\chi'(G)$ of a (multi)graph G, namely the *maximum degree* $\Delta(G)$ and the *density* $w(G)$; the last graph parameter is defined by

$$w(G) = \max_{H \subseteq G, |V(H)| \geq 2} \left\lceil \frac{|E(H)|}{\lfloor \frac{1}{2} |V(H)| \rfloor} \right\rceil .$$

A famous conjecture made, independently, by Goldberg, Anderson and Seymour in the 1970s says that every graph G satisfies

$$\chi'(G) \leq \max\{\Delta(G) + 1, w(G)\}. \tag{1}$$

If $\chi'_f(G)$ denotes the *fractional chromatic index* of G, then (1) implies that every graph G satisfies

$$\chi'_f(G) \leq \chi'(G) \leq \chi'_f(G) + 1. \tag{2}$$

In 1990 Nishizeki and Kashiwagi proved that $\chi'(G) \leq \max\{(11\Delta(G) + 8)/10, w(G)\}$ for every graph G. The proof was based on the so-called critical chain method. A shorter proof of this result was given by Tashkinov in 2000. The main tool in Tashkinov's proof are Tashkinov trees, a common generalization of both Vizing fans and Kierstaed paths. Favrholdt, Stiebitz and Toft extended Tashkinov's method and proved in 2006 that $\chi'(G) \leq \max\{(13\Delta(G) + 10)/12, w(G)\}$ for every graph G. In 2007 Scheide extended this result to $\chi'(G) \leq \max\{(15\Delta(G) + 12)/14, w(G)\}$ for all graphs G. Furthermore, he proved that every graph G satisfy $\chi'(G) \leq \max\{\Delta(G) + \sqrt{\Delta(G)/2}, w(G)\}$ and $\chi'(G) \leq \chi'_f(G) + \sqrt{\chi'_f(G)/2}$. The last result extends a result of Kahn from 1996 as well as a result of Sanders and Steurer from 2005. The proofs of all these results are constructive and based on an extension of Tashkinov's method. In particular, the proof of the inequality $\chi'(G) \leq \max\{\Delta(G) + \sqrt{\Delta(G)/2}, w(G)\} =: \tau(G)$ yields an algorithm that computes, for every graph $G = (V, E)$, an edge colouring of G using at most $\tau(G)$ colours, where the algorithm has time complexity bounded from above by a polynomial in $|V|$ and $|E|$ (and also in Δ).

Robin Thomas, Georgia Institute of Technology, USA

Beyond Grötzsch's theorem

Grötzsch's theorem states that every triangle-free planar graph is 3-colorable. We give a short proof of Grötzsch's theorem and a refinement that leads to a linear-time algorithm to 3-color triangle-free planar graphs. This is joint work with Zdeněk Dvořák and Ken-ichi Kawarabayashi.

In the second part of the talk we discuss the following theorem. There exists an absolute constant c such that if G is a 4-critical triangle-free graph drawn on a surface of Euler genus g, then G has at most cg faces of length at least five, each of length at most cg. This implies a theorem of Thomassen that there are only finitely many 4-critical graphs of girth at least five on any given surface. The second part is joint with Zdeněk Dvořák and Daniel Král.

Carsten Thomassen, Technical University of Denmark

On the theorems of Menger and Kuratowski

Menger's theorem from 1927 on (internally) disjoint paths is one of the most basic tools in graph theory, and there several proofs. It seems less known that the theorem has also enjoyed some attention in topology. In the talk I survey some of the topological versions and present a new general version (joint with Antoine Vella). I also discuss the analogous linkage problem. To deal with this we need a topological version of another fundamental result in graph theory: Kuratowski's theorem.

Mikkel Thorup, AT & T Labs-Research, USA

Efficient Cuts via Greedy Tree Packing

We study a simple greedy tree packing of a graph and use it to derive better algorithms for fully-dynamic min-cut and for the static k-way cut problem.

A greedy tree packing is a sequence of spanning tree where each new tree is a minimum spanning tree with respect to the edge loads from the previous trees, that is, the load of an edge is the number of times it has been used by the previous trees.

A minimum k-way cut is a minimum set of edges whose removal splits the graph in k components. A min-cut is a minimum 2-way cut.

If the (unknown) edge connectivity of the graph is c, we show that if we pack $c^7 \log^3 m$ trees, then some min-cut is crossed exactly once by some tree. This leads to the best fully-dynamic min-cut algorithm (presented at STOC'01)

If we pack $k^3 \log n$ trees, then every minimum k-way cut is crossed $2k-2$ times by some tree. This leads to the best determinstic algorithm for k-way cut (presented at STOC'08)

Jan van den Heuvel, London School of Economics and Political Science,UK

(joint work with Frédéric Havet, Colin McDiarmid and Bruce Reed; Omid Amini and Louis Esperet)

Distance-Two Colouring of Graphs

A *distance-two colouring* of a graph G is a colouring of the vertices of G in which vertices at distance one or two must get different colours. This is obviously the same as a normal (proper) vertex-colouring of the *square* G^2 of G, where G^2 is the graph with the same vertex set as G and with an edge between any two different vertices that have distance at most two in G. Finding the chromatic number of squares of graphs has been an area of intensive research, in particular for planar graphs.

Wegner conjectured in 1977 that the square of a planar graph has chromatic number at most $\frac{3}{2}\,\Delta(G)+1$ for $\Delta(G) \geq 8$, a bound that would be best possible. We show it is at most $\left(\frac{3}{2}+o(1)\right)\Delta(G)$, and indeed this is true for the list chromatic number and for more general classes of graphs.

In 1984, Borodin formulated a similar conjecture on so-called *cyclic colourings* of plane graphs, where vertices incident with the same face need to get different colours. In order to obtain similar asymptotic results for the cyclic chromatic number, we generalise the concept of distance-two colouring.

More specifically, we study the case that we are given a graph G and two sets $A, B \subseteq V(G)$ (not necessarily disjoint). And the requirement is to colour the vertices of B so that (i) adjacent vertices get different colours, and (ii) vertices with a common neighbour from A get different colours. For planar graph we can give asymptotically best possible upper bounds on the number of colours required for such colourings (in terms of the natural degree condition).

Douglas B. West, University of Illinois at Urbana-Champaign, USA

Degree Ramsey and On-line Degree Ramsey numbers

Dating implicitly to Burr, Erdős, and Lovász in 1976, the *degree Ramsey number* of a graph G, written $\mathrm{dr}(G)$, is the least k such that every 2-coloring of the edges of some graph with maximum degree k contains a monochromatic copy of G. The *on-line degree Ramsey number*, written $\mathrm{odr}(G)$, is the least k such that, by presenting edges one-by-one without ever exceeding degree k at any vertex, Builder can force Painter (who must color each edge when it arrives) to produce a monochromatic G. Trivially, $\mathrm{odr}(G) \leq \mathrm{dr}(G) \leq R(G,G)-1$. We present a variety of results and problems about these parameters, particularly for paths, trees, and cycles. This work is joint with Jane Butterfield, Tracy Grauman, Bill Kinnersley, Kevin Milans, and Chris Stocker.

Anders Yeo, Royal Holloway, University of London, UK

(partly joint work with Stephan Thomasse, Michael Henning
and Arezou Soleimanfallah)

Total domination, transversals in hypergraphs and an FPT algorithm!

A set S of vertices in a graph G is a total dominating set of G if every vertex of G is adjacent to some vertex in S. The minimum cardinality of a total dominating set is called the total domination number.

A transversal in a hypergraph, $H = (V, E)$, is a set of vertices $T \subseteq V$, such that every edge in E contains at least one vertex from T.

We will both give bounds on the size of transversals in several kind of hypergraphs and show how these bounds can be used to obtain many different kind of bounds for the total domination number of a graph with properties such as *(i) minimum degree 3 or 4*, *(ii)* 2*-connected*, *(iii) minimum degree 2, containing no induced* 6*-cycles* and *(iv) minimum degree 3, containing no* 4*-cycle*.

As finding transversals in 3-uniform hypergraphs (i.e. all edges contain 3 vertices) has many application, we will also mention a fixed parameter tractable algorithm for this problem. This algorithm can immediately be used in areas such as computational biology (related to phylogenetic trees) and tournaments (finding a minimum feedback vertex set). The time complexity of our algorithm beats all previously know algorithms.

We finally mention several open problems and conjectures.

Daniel Younger, University of Waterloo, Canada

(joint work with Bruce Richter and Cândida Nunes da Silva)

Grötzsch's 3-Colour Theorem in Terms of Integer Flows

Our thread rises from two strands. The first is Carsten Thomassen's 2003 proof of Grötzsch's Theorem (1958). What is special about this proof is that, in place of an appeal to the Euler Polyhedron Formula, Carsten uses a set of colour restrictions on the boundary of the yet uncoloured submap. The proof shows how vertices along the boundary are coloured or the uncoloured submap severed while staying within the set of restrictions. Bruce Richter and I – coauthors in this research – tried to understand Thomassen's technique by constructing a proof using a little different conditions on the boundary. We were joined in this effort by Cândida Nunes da Silva: her fundamental contributions got our proof off the ground.

The second strand is the Steinberg-Younger 1989 proof of Grötzsch's Theorem in dual form, i. e., in terms of 3-flows. This proof, whose main focus was upon an extension to the projective plane, centrally appeals to the Euler Polyhedron Formula. Can this, for the planar case, be replaced by an adaptation of the Thomassen boundary technique? What conditions are maintained and how is the boundary advanced, in this integer flow context?

This talk describes the proof.

Manouchehr Zaker, Institute for Advanced Studies in Basic Sciences, Iran

Lower and upper bounds for chromatic number and some open problems

For any positive integer k and orientation D of a graph G we denote by $\Delta_k(D)$ the largest value t for which there exists a directed path $P = v_1, v_2, \ldots, v_k$ such that $d^+(v_k) = t$, where $d^+(v_k)$ stands for the out-degree of v_k. We first obtain an upper bound for the chromatic number of G in terms of $\Delta_k(D)$. Using this bound we present another upper bound in terms of a new parameter $\Delta_k^{\prec}(G)$ involving the maximum degrees in G. We compare our bound with the coloring number bound and discuss the algorithmic aspects of $\Delta_k(D)$.

The next set of upper bounds are in terms of girth and the booksize of graphs. For any two integers $0 \leq t < k$ by the booksize $b_{t,k}(G)$ of a graph G we mean the maximum number of k-cycles say $C_1, \ldots, C_m$ such that for some path P of length t, $V(C_i) \cap V(C_j) = V(P)$ for any $i \neq j$. Using this concept we improve the best known bound in terms of girth for the chromatic number of graphs when girth is an even integer. We generalize the results for even-girth of graphs.

Finally we obtain some lower bounds in terms of maximum or average degree of graphs. We show that for any tree T and integer t the chromatic number of any $(T, K_{2,t})$-free graph is lower bounded by a fraction of average degree. A lower bound is also given in terms of the maximum even-hole of graphs.

Xuding Zhu, National Sun Yat-sen University, Taiwan

Bipartite density and bipartite ratio of triangle-free subcubic graphs

This talk shows that if G is a triangle-free graph of maximum degree 3 then G has an induced bipartite graph with $5|V(G)|/7$ vertices, with two exceptions: the Petersen graph and the dodecahedron. Also G has a spanning bipartite graph with $17|E(G)|/21$ edges with seven exceptional graphs.

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