2014 組合數學新苗研討會

國立台灣師範大學數學系

2014 年 8 月 2 日至 3 日

大會演講

李國偉　教授　中央研究院

林強　　教授　中央大學數學系

地點

台灣師範大學公館校區 科教大樓 5 樓演講廳

贊助單位

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大會宗旨

組合數學新苗研討會最初由中央研究院數學研究所李國偉教授在 1990 年發起，每年由各大學或相關研究機構輪流主辦，此研討會所舉辦的目的在於提供台灣組合數學相關領域的應屆碩博畢業生與相關研究人員，發表其研究成果，互相交流或討論，以獲得後續研究方向的機會。除此之外，也提供與會者互相聯絡、切磋及觀摩的平台。

適逢今年是第 25 週年舉辦，我們邀請李國偉教授，與林強教授，擔任大會演講，兩位資深教授在組合領域上有相當豐碩的研究成果，同時，他們也都是第一屆新苗研討會的發起者，相信其研究經驗能夠給予後輩良好的啟發與鼓勵。此研討會對於鼓勵青年新進之輩與國內學者專家之研究交流有很大的助益，故組合數學新苗研討會，一直是台灣組合數學界中相當重要的研討會之一。此外，於今年還特地邀請大陸與日本組合領域的博士生一起來參與盛會，相信藉由這樣的交流，能為組合新苗研討會帶來新的風貌。

新苗二十五年

新苗研討會是台灣組合數學界的年度盛事。只要在國內的組合數學圈子，提起新苗一定有很多故事可以說 — 我還記得某一次茶敘時大家笑著說:「“離散”與“組合”這兩個字面意義相反的詞居然是同一件事!」

開辦新苗研討會是令人佩服的遠見。多年來，新苗見證了數以百計的新科碩士與博士的畢業，培養了許多人才，見證了台灣組合數學從無到有的興盛。組合數學這個相對年輕的領域能夠在台灣形成一個不可忽視的研究聚落，新苗研討會開疆闢土的開拓功不可沒。

而新苗今年滿二十五歲了 — 和應屆的碩士畢業生一樣大！一個研討會可以二十五週年真是不簡單的。籌備委員會花了許多的時間，上下蒐羅迄今的所有新苗書面議程，放在今年的網頁上。非常幸運的是，我們找到了第一屆的議程。1990 年的第一屆新苗在中央研究院舉行，六個 sessions 的主持人中，包括了發起人李國偉教授與今年即將榮退的林強教授。多年來兩位教授在台灣組合界培育了許多學者持續活躍於學界，對台灣組合界有很大的貢獻。我們非常榮幸邀請兩位教授擔任今年的大會演講。

承襲往年作法，今年我們亦有最佳論文的評選。但無論有沒有得獎，都祝福所有從新苗畢業的新科碩士與博士。各位是台灣組合數學界的新苗，有朝一日將成為參天大樹。恭喜畢業!

謹代表籌備委員會歡迎大家蒞臨今年的新苗研討會。這是台師大首度承辦，雖只有短短的兩天，我們仍希望能盡力做到最好。張飛黃與郭君逸兩位教授扛下了大部分的籌備工作，林延輯與徐泰煒 (第一屆新苗的演講者，亦為林強教授的第一位學生) 兩位教授亦協助甚多。倘有不盡完美之處，就請多多包涵。

二十五年是一個里程碑。承先啟後，讓我們一起努力，往下一個二十五年邁進。

國立台灣師範大學數學系
“教官”/游森棚
2014/8/2

Contents

2014 組合數學新苗研討會議程

8 月 2 日 (六)

08:45–09:30	報到 (科教大樓五樓)			
09:30–09:45	開幕暨來賓致詞			主持：游森棚
09:50–10:35	大會演講：林強教授 (中央數學) Graph labellings: splittable graph and antimagic graphs			主持：徐泰煒
10:35–11:00	陳珍君 (中央數學)			
11:00–11:20	茶歇			
Session 1	地點：501		地點：503	
11:20–11:40	謝孟萍 (中央數學)	主持：黃國卿	簡維良 (台師數學)	主持：顏經和
11:40–12:00	王偉名 (政大應數)		余冠儒 (交大應數)	
12:00–14:00	午餐			
14:00–14:25	邀請演講：晋亚磊 (上海交通大学) The spectral redius of connected graphs with the independence number			主持：嚴志弘
14:25–14:50	邀請演講：卢晓南 (日本名古屋大学) On affine-invariant strictly cyclic Steiner quadruple systems			
14:50–15:10	茶歇			
Session 2	地點：501		地點：503	
15:10–15:30	林伯融 (交大應數)	主持：傅東山	蔡睿翊 (交大應數)	主持：張定邦
15:30–15:50	陳律仲 (暨大資工)		林筱芸 (中山應數)	
15:50–16:10	許博喻 (交大應數)		張宏名 (高師數學)	
Session 3	地點：501		地點：503	
16:20–16:40	林凡軒 (交大應數)	主持：張惠蘭	簡廷豐 (台大數學)	主持：李渭天
16:40–17:00	蔡一慈 (高大應數)		吳熹皓 (交大應數)	
17:00–17:20	蔡宜霖 (高大應數)			
17:20–	大合照 & 晚宴			

8 月 3 日 (日)

08:30–09:15	大會演講：李國偉教授 (中研院數學所) Rota's Lessons	主持：傅恆霖
09:15–09:40	邀請演講：賴欣豪教授 (高師數學) Lovász Local Lemma, Entropy Compression and Graph Colorings	
09:40–10:00	茶歇	
Session 4		
10:00–10:25	廖芳儀 (中研院數學所)	主持：林武雄
10:25–10:50	邱鈺傑 (交大應數)	
10:50–11:15	連敏筠 (交大應數)	
Session 5		
11:25–11:50	姜宏興 (中原數學)	主持：史青林
11:50–12:15	羅淑玟 (淡江數學)	
12:15–14:00	午餐	
14:00–14:25	邀請演講：林辉球 (华东理工大学) Which connected graphs are determined by their distance spectra	主持：林延輯
14:25–14:50	李忠逵 (交大應數)	
Session 6		
15:00–15:25	李光祥 (交大應數)	主持：陳宏賓
15:25–15:50	陳聖華 (台大數學)	
16:00–16:30	頒獎與閉幕	

大會演講

Graph Labellings: Splittable Graphs and Antimagic Graphs

Chiang Lin (林強 教授)
Department of Mathematics, National Central University (中央大學數學系)

1. Splittable Graph.

   Let G be a graph. Then G is *t-splittable* if the edges of G can be partitioned into t isomorphic graphs. A trivial necessary condition for G to be t-splittable is that $|E(G)| = 0 \pmod{t}$.

   (1) We give the necessary and sufficient conditions for the spiders to be t-splittable.

   (2) We investigate the 2-splittabilities of multipaths and multicycles with multicity 2, respectively.

2. Antimagic Graphs.

   Let G be a graph. If $f : E(G) \to A$ where $A \subset \mathcal{C}$, then for $v \in V(G)$, the *vertex sum* of f at v is $f^+(v) = \sum_{uv \in E(G)} f(uv)$. If there exists $f : E(G) \to \{1, 2, \ldots, |E(G)|\}$, 1-1 such that all vertex sums of f are distinct, then G is *antimagic*. A well-known conjecture is that every simple connected graph except K_2 is antimagic. We investigate the antimagicnesses of disconnected graphs and multigraphs.

   (a) We investigate the antimagicness of star forests.

   (b) The union of a path (of order ≥ 3) and a star (of order ≥ 3) is antimagic.

   (c) Any multipath with multiplicity 2 and maximum degree ≤ 3 is antimagic.

3. A Generalization of Antimagic Graphs.

   Let G be a graph. If $A \subset \mathcal{C}$ with $|A| = |E(G)|$ and there exists $f : E(G) \to A$, 1-1 such that all $f^+(x)$ ($x \in V(G)$) are distinct, then G is *A-antimagic*. If $B \subset \mathcal{C}$ with $|B| \geq |E(G)|$, and G is A-antimagic for every A with $A \subset B$ and $|A| = |E(G)|$, then G is *B-antimagic*. Trivially, for a graph G, if $B_1 \subset B_2 \subset \mathcal{C}$, $|B_1| \geq |E(G)|$, and G is B_2-antimagic, then G is B_1-antimagic.

   (a) Let G be a graph. Then G is $\mathbb{R}$-antimagic if and only if G is $\mathbb{C}$-antimagic.

   (b) Any path of order ≥ 5 is $\mathbb{R}$-antimagic.

Rota's Lessons

Ko-Wei Lih (李國偉 教授)
Institute of Mathematics, Academia Sinica (中研院數學所)

Gian-Carlo Rota(1932 – 1999) 是 20 世紀引導組合數學成為重要數學分支的先驅之一，他曾是麻省理工學院唯一的數學與哲學合聘教授。Rota 學養淵博文采華麗，在 Fabrizio Palombi 為他編的文集 "Indiscrete Thoughts" 裡，有很多有意思又充滿智慧的言論。本次演講將介紹該書第 18 章 "Ten Lessons I Wish I Had Been Taught" 與第 19 章 "Ten Lessons for the Survival of a Mathematics Department" 裡 Rota 給我們的忠告。

邀請演講

Lovász Local Lemma, Entropy Compression and Graph Colorings

Hsin-Hao Lai (賴欣豪 教授)
Department of Mathematics, National Kaohsiung Normal University
(高雄師範大學數學系)

In the 70's, Lovász introduced the Lovász local lemma. Lovász local lemma is a powerful probabilistic method and has been used widely in the study of graph colorings.

In [1], an inspiring method, called the entropy compression, was introduced. It is an algorithmic version of Lovász local lemma and has been used in the study of graph colorings.

In this talk, I will introduce the relation between Lovász local lemma and entropy compression. Also, I will introduce the results of graph colorings obtained by entropy compression and describe the idea behind the method.

Keywords: Lovász Local Lemma, Entropy Compression, Graph Coloring.

Reference

[1] R. Moser, G. Tardos, A constructive proof of the general Lovász local lemma, J. ACM 57 (2010), Art. 11.

Which connected graphs are determined by their distance spectra

Huiqiu Lin (林辉球)
Department of Mathematics, East China University of Science and Technology (上海华东理工大学数学系)

The distance matrix $D(G) = (d_{ij})_{n\times n}$ of a connected graph G is the matrix indexed by the vertices of G, where d_{ij} denotes the distance between the vertices v_i and v_j. Two nonisomorphic graphs with the same D-spectra are called cospectral. We say that a graph is determined by the D-spectra if there is no other nonisomorphic graph with the same D-spectra. In this talk, we characterize some graphs which are determined by their D-spectra.

The spectral radius of connected graphs with the independence number*

Ya-Lei Jin (晋亚磊)
Department of Mathematics, and MOE-LSC,
Shanghai Jiao Tong University (上海交通大学数学系)

In this talk, we investigate some properties of the Perron vector of connected graphs. These results are used to characterize all extremal connected graphs which attain the minimum value among the spectral radii of all connected graphs with order $n = k\alpha$ and the independence number α. Moreover, all extremal graphs which attain the maximum value among the spectral radii of clique trees with order $n = k\alpha$ and the independence number α are characterized.

*This work is joint with my advisor Xiao-Dong Zhang(张晓东教授).

On affine-invariant strictly cyclic Steiner quadruple systems

Xiao-Nan Lu (卢晓南)
Graduate School of Information Science, Nagoya University, Nagoya, Japan (名古屋大学大学院情报科学研究科数理系)
Advisor: Professor Masakazu Jimbo

A Steiner quadruple system of order v, denoted by SQS(v), is a pair $(V, \mathcal{B})$, where V is a finite set of v elements, and $\mathcal{B}$ is a collection of 4-elements subsets of V, called blocks or quadruples, such that each 3-elements subset (triple) of V is contained in exactly one block in $\mathcal{B}$.

Let G be a permutation group on V. If G leaves $\mathcal{B}$ invariant, then G is called an automorphism group of SQS(v). In particular, an SQS(v) is said to be cyclic if it admits a cyclic group of order v. Accordingli, $\mathcal{B}$ can be partitioned into orbits under the cyclic permutations. Furthermore, the orbit whose cardinality is equal to v is said to be full. If all the orbits are full, then the SQS(v) is said to be strictly cyclic, denoted by sSQS(v).

Without loss of generality, for a cyclic SQS $(V, \mathcal{B})$, we can identify V with $\mathbb{Z}_v$, the additive group of integers modulo v. Moreover, we consider the multiplicative group of all units of $\mathbb{Z}_v$, say $\mathbb{Z}_v^\times$. If an SQS admits all the elements in $\mathbb{Z}_v^\times$ as multipliers, then it is said to be affine-invariant.

It is easy to show that an sSQS(v) exists only if $v \equiv 2, 10 \pmod{24}$. The constructions of sSQS's was first studied by Köhler in 1979. Köhler proposed a graph named after him, and proved that an sSQS(v) exists if and only if the corresponding Köhler's graph has a 1-factors. But there are few constructions known for sSQS(v) which are independent from Köhler's.

In this talk, we suppose $v = 2p$, where $p \equiv 1, 5 \pmod{12}$ is an odd prime, and focus on the constructions of affine-invariant sSQS(v). By means of a system of generators of projective special linear group PSL$(2, p)$, we define two families of graphs algebraically whose 1-factors play an important role in our constructions. By computer search, we also verify that all these graphs for $p < 100,000$ have 1-factors. Futhermore, we give recursive constructions for affine-invariant sSQS($2p^m$), for any positive integer m.

Keywords: Steiner quadruple system, projective linear group, 1-factor.

博士

Maximum packings and minimum coverings of multigraphs with paths and stars

Chun-Cheng Chen (陳珍君)
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Joint work with Hung-Chih Lee(李鴻志)

Let F, G, and H be multigraphs. An (F, G)-decomposition of H is an edge decomposition of H into copies of F and G using at least one of each. For subgraphs L and R of H, an (F, G)-packing (resp. (F, G)-covering) of H with leave L (resp. padding R) is an (F, G)-decomposition of $H - E(L)$ (resp. H+E(R)). An (F, G)-packing (resp. (F, G)-covering) of H with the largest (resp. smallest) cardinality is a maximum (F, G)-packing (resp. minimum (F, G)-covering), and its cardinality is referred to as the (F, G)-packing number (resp. (F, G)-covering number) of H. Let k be a positive integer. A k-path, denoted by P_k, is a path on k vertices. A k-star, denoted by S_k, is a star with k edges. In this paper, we determine the packing numbers and the covering numbers of both λK_n and $\lambda K_{n,n}$ with $(k+1)$-paths and k-stars for any λ, n and k. Moreover, necessary and sufficient conditions for the existence of (P_{k+1}, S_k)-decompositions of both λK_n and $\lambda K_{n,n}$ are given.

Keywords: Packing, Covering, Path, Star.

Factorizations of Suffixes of Two-Way Infinite Characteristic Words

Fang-Yi Liao (廖芳儀)
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Chung Yuan Christian University (中原大學應數系)

Advisor: Wai-Fong Chuan(郭蕙芳)

Let α be an irrational number between 0 and 1 with continued fraction expansion $[0; a_1+1, a_2, a_3, \cdots]$, where $a_n \geq 1$ $(n \geq 1)$. Define a sequence of numbers $\{q_n\}_{n\geq 1}$ by $q_{-1} = 1$, $q_0 = 1$, $q_n = a_n q_{n-1} + q_{n-2}$ $(n \geq 1)$. For each integer $k \geq -1$, we consider the *kth-order factorization* of each suffix H of a two-way infinite characteristic word of α of the form: $H = u_k u_{k+1} u_{k+2} \cdots$, where the length of the factor u_i is q_i $(i \geq k)$. We show that in such a factorization, either all u_i are singular words, or there exists a nonnegative integer q such that H begins with q singular words, and $u_{k+q}, u_{k+q+1}, u_{k+q+2}, \cdots$ are α-words. Moreover, the labels of these α-words are uniquely determined by the F-representation of a nonnegative integer obtained from the position of H in the two-way infinite characteristic word.

Next, define *Markov word pattern of order k* $(k \geq -1)$ generated by a pair of seed words (u, v) as follows: $M_k(u, v) = z_1 z_2 z_3 \cdots$, where $z_1 = u$, $z_2 = v$, and $z_i = z_{i-1}^{a_{i+k-1}-1} z_{i-2} z_{i-1}$ $(i \geq 3)$. We show that each suffix H of each two-way infinite characteristic word is a Markov word pattern, and the pairs of its seed words obtained are adjacent α-words; we also find all possible pairs of seed words of H which are pairs of adjacent α-words. On the other hand, we show that each Markov word pattern generated by any pair of adjacent α-words is a suffix of a two-way infinite characteristic word.

Finally, we study the set V of all pairs of adjacent α-words. We describe the elements of V in terms of cyclic shifts, lexicographic order, and labels. For each α-word w, we find all possible words u such that (u, w) (resp., (w, u)) are pairs of adjacent α-words. Also, we construct a directed graph $\mathbf{G}_\alpha$ consisting of the vertex set of all α-words and the edge set V, and use such a graph to illustrate the results about adjacent α-words, and the suffixes of the two-way infinite characteristic words that they generate.

Keywords: Two-way infinite characteristic word, Factorization, Markov word pattern, Seed word, Adjacent α-word.

Self-stabilizing Minimal Dominating Set Algorithms of Distributed Systems and the Signed Star Domination Number of Cayley Graphs

Well Y. Chiu (邱鈺傑)
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National Chiao Tung University (交通大學應數系)
Advisor: Chiuyuan Chen(陳秋媛)

The study of the domination problem in graph theory began in the nineteen-sixties. A distributed system such as an ad hoc network can be modeled by an undirected simple graph $G = (V, E)$, where V represents the set of nodes (i.e., processes) and E represents the set of interconnections between processes of the distributed system. A subset D of the vertex set V of G is a dominating set if each vertex $v \in V$ is either a member of D or adjacent to a vertex in D. A dominating set of G is a minimal dominating set (MDS) if none of its proper subsets is a dominating set of G. An MDS has an application of clustering in wireless networks and is maintained for minimizing the number of required resource centers.

Self-stabilization is a concept of designing a distributed system for transient fault toleration and was introduced by Dijkstra in 1974. A distributed system is self-stabilizing if, regardless of its initial configuration, the system is guaranteed to reach a legitimate (i.e., correct) configuration in a finite time. Here the system configuration consists of the state of every process. A self-stabilizing algorithm comprises a collection of rules and each rule has a trigger precondition and an action. The action changes the state of the node by updating its variables. An execution of a rule is called a move. The performance of the proposed algorithms of this thesis is measured by the total number of moves executed by an algorithm. Various execution models have been used in self-stabilizing algorithms and these are encapsulated with the notion of daemons. A daemon can be fair or unfair. It is well-known that an unfair distributed daemon is more practical than other types of daemons.

Let n denote the number of nodes (processes) in a given distributed system. In 2007, Turau proposed the first linear-time self-stabilizing algorithm for the MDS problem under an unfair distributed daemon; this algorithm stabilizes in at most $9n$ moves. In 2008, Goddard et al. improved the result to a $5n$-move algorithm. It is interesting to develop an algorithm that takes less moves than the best known result—$5n$ moves using an unfair distributed daemon. In this thesis, we will present a $4n$-move self-stabilizing MDS algorithm using an unfair distributed daemon.

It is desired that an MDS algorithm is MDS-silent, which means that if the original configuration of the distributed system is already an MDS, then the algorithm should not make any move. Note that in the normal model, a node can only access the information of its 1-hop neighbors and we call such information distance-1 information. Unfortunately, in this thesis we will prove that distance-1 information is not sufficient for building up an MDS-silent algorithm for a distributed system. What will happen if a node can access the information of its k-hop neighbors for $k \geq 2$? In this thesis, we will discuss this problem and propose a new performance measure, called stableness, for self-stabilizing MDS algorithms. We also generalize this result to categorize all self-stabilizing algorithms into four levels. In particular, we will show that a self-stabilizing MDS-silent algorithm can be built up under the distance-2 model and the stabilizing time is upper bounded by $2n$.

Let G be a simple connected graph with vertex set $V(G)$ and edge set $E(G)$. A function $f : E(G) \rightarrow \{-1, 1\}$ is called a signed star dominating function (SSDF) on G if $\sum_{e \in E_G(v)} f(e) \geq 1$ for every $v \in V(G)$, where $E_G(v)$ is the set of all edges incident to v. The signed star domination number of G is defined as $\gamma_{SS}(G) = \min\{\sum_{e \in E(G)} f(e) |\ f$ is an SSDF on $G\}$. Let D be a finite digraph with vertex set $V(D)$ and arc set $A(D)$. For each vertex $v \in V(D)$, let $A(v)$ be the set of all out-going arcs from v. By replacing $E(v)$ by $A(v)$, one can define SSDF on D and $\gamma_{SS}(D) = \min\{\sum_{a \in A(D)} f(a) \mid f$ is an SSDF on $D\}$. Let Γ be a finite nontrivial group and S be a nonempty subset of Γ. The Cayley digraph $Cay_D(\Gamma, S)$ is the digraph whose vertices are the elements of Γ, and there is an arc from α to $\alpha\sigma$ whenever $\alpha \in \Gamma$ and $\sigma \in S$. Let Ω be a symmetric generating subset of nonidentity elements of Γ. The Cayley graph $Cay(\Gamma, \Omega)$ corresponding to Γ and Ω is the ordinary graph with vertex set Γ and edge set $E = \{\{\alpha, \alpha\sigma\} \mid \alpha \in \Gamma, \sigma \in \Omega\}$. In this thesis, we obtain exact values for the signed star domination number of all Cayley digraphs $Cay_D(\Gamma, S)$ and certain classes of Cayley graphs $Cay(\Gamma, \Omega)$, which is later generalized to $\{2, 1\}$-factorable graphs.

Keywords: self-stabilizing, minimal dominating set, stableness, signed star domination number.

Decycling Number on Graphs and Digraphs

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Advisor: Hung-Lin Fu(傅恆霖)

A set of vertices of a graph or an digraph whose removal induces an acyclic graph is referred as a *decycling set*, or a *feedback vertex set*, of the graph. The minimum cardinality of a decycling set of a graph G is referred to as the *decycling number* of G.

The problem of determining the decycling number has been proved to be *NP*-complete for general graphs, which also shows that even for planar graphs, bipartite graphs and perfect graphs, the computation complexity of finding their decycling numbers is not reduced.

The problem of destroying all cycles in a graph by deleting a set of vertices originated from applications in combinatorial circuit design. Also, it has found applications in deadlock prevention in operating systems, the constraint satisfaction problem and Bayesian inference in artificial intelligence, monopolies in synchronous distributed systems, the converters' placement problem in optical networks, and VLSI chip design.

In this talk, we introduce the decycling number of graphs and also digraphs. The graphs we consider are outerplanar graphs and grid graphs $P_m \Box P_n$. For the first class of graphs, we characterize their decycling number by way of the cycle packing number and for grid graphs, we improve the known results to obtain either tight bounds or exact values. On digraphs, we consider generalized Kautz digraphs and generalized de Bruijn digraphs. Mainly, we use a novel idea in which we find a sequence of subsets of vertex set satisfying certain conditions and then obtain a decycling set. This provides an upper bound of the decycling number of digraphs we consider. Note that this idea can be applied to find the decycling set of general digraphs.

Keywords: Decycling Number, Feedback vertex number, Outerplanar Graphs, $P_m \Box P_n$, Generalized Kautz Digraphs, Generalized de Bruijn Digraphs.

Optimally ℓ-Pebbling Cycles

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Joint work with Chin-Lin Shiue and M. M. Wong

Let G be a graph. A *distribution* of pebbles of G is a a function $\delta : V(G) \rightarrow N \cup \{0\}$. In a graph with a distribution of pebbles, a pebbling move consists of removing two pebbles from one vertex and then placing one pebble at an adjacent vertex. A pebbling type α of G is a mapping from $V(G)$ into $\mathbb{N} \bigcup \{0\}$. A distribution δ is called an *α-pebbling* if whenever we choose a target vertex v, we can move $\alpha(v)$ pebbles to v by applying pebbling moves repeatedly (if necessary). An it ℓ-pebbling of G is an α-pebbling of G for which $\alpha(v) = \ell$ for each $v \in V(G)$, where ℓ is a positive integer. The optimal α-pebbling number $f'_\alpha(G)$ of G is the minimum number of pebbles used in an α-pebbling of G. We denote $f'_\alpha(G) = f'_\ell(G)$ if $\alpha(v) = \ell$ for each $v \in V(G)$. The *optimal pebbling number* of a graph G is the optimal 1-pebbling number of G and denoted by $f'(G)$. In this paper, we first find the optimal 2-pebbling numbers and optimal 3-pebbling numbers of the cycle graph C_n. Second, we find the upper bound and lower bound of C_n. Lastly apply them to aproach optimal ℓ-Pebbling of C_n.

Keywords: optimal pebbling number, cycle.

A study of bull-design

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Advisor: Chin-Mei Kau Fu(高金美)

A complete graph K_n is a simple graph of order n whose vertices are pairwise adjacent. A decomposition of graph G is a collection $\mathcal{H} = \{H_1, H_2, \ldots, H_k\}$ of subgraphs of G, such that $E(H_i) \cap E(H_j) = \emptyset$ $(i \neq j)$ and $E(H_1) \cup E(H_2) \cup \cdots \cup E(H_k) = E(G)$. Let H be a graph, an H-design of a complete graph K_n, denoted by (K_n, H), is a pair $(X, \mathcal{B})$, where X is the vertex set of the complete graph K_n and $\mathcal{B}$

is a collection of subgraphs of K_n, called blocks, such that each block is isomorphic to H, and any edge of K_n is contained in exactly one subgraph of K_n. Furthermore, G has an H-decomposition or G can be decomposed into H, if H_i is isomorphic to H $(1 \leq i \leq k)$. Therefore, a (K_n, H)-design exists means K_n has an H-decomposition.

A bull is a graph B which is obtained by attaching two edges to two vertices of a triangle. A $(K_n, \mathcal{B})$-design is called a bull-design of order n.

In Chapter 2, we show that the necessary and sufficient condition of a bull-design of order n exist precisely when $n \equiv 0, 1 \pmod 5$.

In Chapter 3, we consider the maximum packing of bull-design of order n. We obtain that the leave of maximum packing is a set of one edge if $n \equiv 2$ or $4 \pmod 5$ and a set of three edges if $n \equiv 3 \pmod 5$. By the above results, we obtain that the necessary and sufficient conditions for the existence of bull-designs of a complete multi-partite graph λK_n are the follows: $\lambda \not\equiv 0 \pmod 5$ and $n \equiv 0, 1 \pmod 5$, or $\lambda \equiv 0 \pmod 5$ and for all n.

In Chapter 4, we obtain that the spectrum of bull-design of order n intersecting in pairwise disjoint blocks is $0, 1, 2, \ldots, [n/5]$, when $n > 5$ and $n \equiv 0, 1 \pmod 5$, and the spectrum of bull-design of order 5 intersecting in pairwise disjoint blocks is 0. We also show that the spectrum of triangle intersection numbers of two bull-design of order n is $0, 1, 2, \ldots, n(n-1)/10$, for $n \equiv 0, 1 \pmod 5$.

In Chapter 5, we obtain that a bull-design of order n can be embedded in a bull-design of order m if and only if $m \geq 3n/2 + 1$ or $m = n$. This produces a generalization of the Doyen-Wilson theorem for bull-designs.

Keywords: Decomposition, bull-design, Packing, Intersection, Doyen-Wilson theorem.

A General Framework for Central Limit Theorems of Additive Shape Parameters in Random Digital Trees

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Tries, PATRICIA tries and (bucket) Digital Search Trees are fundamental data structures in computer science with numerous applications. In recent papers, a

general framework for obtaining the mean and variance of additive shape parameters of tries, PATRICIA tries and DSTs under the Bernoulli model was proposed. Later on, we showed that a slight modification of the frameworks yields a central limit theorem for shape parameters, too. This central limit theorem contains many of the previous central limit theorems from the literature and it can be used to prove recent conjectures and derive new results. As an example of the trie case, we will consider a refinement of the size of tries and PATRICIA tries, namely, the number of nodes of fixed outdegree and obtain (univariate and bivariate) central limit theorems. For the DSTs case, we use 2-protected node as an example to illustrate how the framework will work.

Spectral Excess Theorem and its Applications

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Advisor: Chih-wen Weng(翁志文)

The spectral excess theorem gives a quasi-spectral characterization for a regular graph to be distance-regular. An example demonstrates that this theorem cannot directly apply to nonregular graphs. In order to make it applicable to nonregular graphs, a 'weighted' version of the spectral excess theorem is given. For application, we show that a graph with odd-girth $2d+1$ is distance-regular, generalizing a result of van Dam and Haemers. We then apply this line of study to the class of bipartite graphs. It is well-known that the halved graphs of a bipartite distance-regular graph are distance-regular. Examples are given to show that the converse does not hold. Thus, a natural question is to find out when the converse is true. We give a quasi-spectral characterization of a connected bipartite weighted 2-punctually distance-regular graph whose halved graphs are distance-regular. In the case the spectral diameter is even we show that the graph characterized above is distance-regular.

Keywords: Distance-regular graph, Distance matrices, Predistance polynomials, Spectral diameter, Spectral excess theorem.

Covering Problems in Graphs

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Covering problems in graphs are optimization problems about covering the vertex set $V(G)$ or the edge set $E(G)$ of a graph G under some additional restrictions. In other words, a *graph covering* of G is a collection of vertex/edge subsets of G such that each vertex or each edge of G is belonged to at least one subset in this collection. Graph covering enjoys many practical applications as well as theoretical challenges. It is heavily used in various fields such as biochemistry (genomics), electrical engineering (communication networks and coding theory), computer science (algorithms and computation) and operations research (scheduling) etc.

In this thesis, we study six covering problems in graphs, which study the optimally of the following related functions. A *strong edge-coloring* is a function that assigns to each edge a color such that any two edges within distance two apart receive different colors. An *edge Roman dominating function* is the edge version of a Roman dominating function, that is, a function $f\colon E(G) \to \{0, 1, 2\}$ such that every edge e with $f(e) = 0$ is adjacent to some edge e' with $f(e') = 2$. More generally, for a fixed positive integer k, a *k-power Roman dominating function* is a function $f\colon V(G) \to \{0, 1, \ldots, k\}$ such that every vertex u with $f(u) = 0$ is adjacent to some vertex v with $f(v) = i \leq k$ within distance i. A *distance edge cover* is a generalization of an edge cover, that assigns each edge a label such that every vertex is within distance j from some edge with label j. A *modular orientation* is an orientation of edges such that the in-degree equals to the out-degree of each vertex. A *relaxation procedure* is a series of relabeling by changing the sign of a negative vertex and sharing the difference equally to its neighbors.

The purpose of this thesis is to study the above mentioned graph covering problems from algorithmic, algebraic and probabilistic point of view. In particular, we give exact values and/or upper/lower bounds for related parameters of these problems. New technics are developed to established interesting results, including the proofs/dis-proofs of some known conjectures.

碩士

The 3-split of multipaths and multicycles with multiplicity 2

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Let G be a graph and t be a positive integer. A t-split of G is a partition of the edges of G into t isomorphic subgraphs. A graph is said to be t-splittable if it has a t-split.

In this thesis we prove the following results.
Theorem. Let Q be a multipath with multiplicity 2 such that $|E(Q)|$=0 (mod 3). Then Q is 3-splittable.
Theorem. Let C be a multicycle with multiplicity 2 such that $|E(C)|$=0 (mod 3). Then C is 3-splittable.

Diffy Hexagons

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In this thesis, we study the Diffy Hexagons: Initially, we regard a Ducci sequence as a Diffy Hexagon game and discuss some properties about Ducci sequences. However, a Ducci sequence isn't actually a Diffy Hexagon game due to the fact that regular hexagons has some symmetries under rotations and reflections, but the Ducci sequences don't. Therefore, we apply an identification in the end.

Keywords: Cycles, Diffy Hexagons, Ducci processes, Ducci sequences, Periods, Similar cycles.

On the distribution of the leading statistic for the bounded deviated permutations

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The purpose of the thesis is to investigate the distribution of the initial number in the bounded deviated permutations $S_{n+1}^{\ell,r}$, assuming the uniform distribution in $S_{n+1}^{\ell,r}$.

Define the random variable X_n to take the value k if $\pi_1 = k+1$ $\pi = \pi_1\pi_2\cdots\pi_{n+1} \in S_{n+1}^{\ell,r}$. By considering the bivariate generating function $A(z,u)$, we could calculate the expected value and the standard deviation for X_n. The method is then applied to two specific cases, $S_{n+1}^{1,2}$ and $S_{n+1}^{2,2}$. Since the coefficients $\lambda_{n,k}$ of the bivariate generating function do not have a closed form, we will apply the Hayman method to get its asymptotic formula. Finally, by running computer programs, the convegences of the normal distribution of $S_{n+1}^{1,2}$ and $S_{n+1}^{2,2}$ are verified.

The Number of 2-Protected Nodes in Tries and PATRICIA Tries

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Digital trees are data structures which are of fundamental importance in Computer Science. Recently, so-called 2-protected nodes have attracted a lot of attention. For instance, J. Gaither, Y. Homma, M. Sellke, and M. D. Ward derived an asymptotic expansion for the mean of the number of 2-protected nodes in random tries.

Moreover, J. Gaither and M. D. Ward considered the variance and conjectured a central limit theorem.

In this talk, we will explain our recent results on the number of 2-protected nodes in tries and PATRICIA tries. More precisely, we will derive asymptotic expansions of moments and prove the conjectured central limit theorem of J. Gaither and M. D. Ward. An interesting aspect of our work is that our results contain divergent series which however become convergent (and yield correct results) by appealing to the theory of Abel summability.

Keywords: digital tree, 2-protected nodes, moments, central limit theorem.

Perfect Secret Sharing Schemes for Access Structures Based on Graphs

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A perfect secret sharing scheme based on a graph G is a randomized distribution of a secret among the vertices of the graph so that the secret can be recovered from the information assigned to the endvertices of any edge, while the total information assigned to an independent set of vertices is independent (in statistical sense) of the secret itself.

The (worst case) *information ratio* of G is the largest lower bound on the amount of information some vertex must remember for each bit of the secret. Using entropy method, we calculate a lower bound on the information ratio for an infinite class of graphs we consider in this thesis. We also use the generalized vector space construction to construct perfect secret sharing schemes with information ratio 2 for two subclasses of graphs. This upper bounded is very close to our lower bound in some circumstances, which means the secret sharing schemes we construct are in fact very good.

A Study on Quality-Enhanced Visual Multi-Secret Images Sharing Schemes

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Visual secret sharing is a method of encrypting images. In 2012, a multiple visual secret sharing scheme by shifting random grid was proposed by Chang. In this scheme, multiple secret-images can be encrypted into two share images. However, the *distortion* of this scheme is quite high (especially when the number of secret images are more). In order to decrease the distortion of this scheme, we propose three improved multiple visual secret sharing schemes by shifting random grid.

The first method of our schemes is *increasing the number of fragments* (*INF*, for short). The second is *increasing the number of shares* (*INS*, for short). The third is *distributing the black pixels evenly on shares* (*DBPEOS*, for short), this method not decreases the quantity of distortion but increases the evenness of black pixels.

In addition to less distortion, INS develops two new modes for mobile devices. Therefore, our proposed schemes can be used for more applications.

Keywords: visual secret sharing, random grid, multiple secret-images, mobile devices.

The Minimum Rank of Buds

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For a simple graph G of order n with vertex set $[n] = \{1, 2, \cdots, n\}$, an $n \times n$ real symmetric matrix A, whose ij-th entry is not zero if and only if there is an edge joined i and j in G, is said to be associated with G. The minimum rank of G is defined to be the smallest possible rank over all symmetric real matrices associated

with G. A bud based on $[n-m]$ is a graph G with vertex set $V(G) = [n]$ satisfying the following axioms:

(i) The subgraph of G induced on $[n-m]$ is a cycle C_{n-m}, and the subgraph induced on $[n] \setminus [n-m]$ has no edge.

(ii) The cycle C_{n-m} can be parted into m disjoints paths, and the length of these paths are at least 2. For all vertex v in $[n] \setminus [n-m]$, v has at least three neighbors in the same path. Any two vertices in $[n] \setminus [n-m]$ are not connected to the same path.

In the thesis we will show that a bud based on $[n-m]$ has minimum rank $n-m-2$.

Keywords: Graph, Minimum rank, Bud.

Mathematical Properties and Construction of Quantum Error Correcting Codes

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This thesis introduces about the quantum error correcting codes in the viewpoint of classical error correcting codes. We also introduce some construction and characterization of quantum error correcting codes. Thereafter, we give a construction of quantum error correcting codes associated with graphs, which generalizes a previous result that excludes the binary case so that it is valid for all cases.

Keywords: quantum error correcting codes,graph.

The study of r-locating-dominating codes in paths

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The locating-dominating code of graph was introduced by Colbourn, Slater, and Stewart. Slater proved that $M_1^{LD}(P_n) = \lceil \frac{2n}{5} \rceil$. Honkaia proved that $M_2^{LD}(P_n) = \lceil \frac{n+1}{3} \rceil$. Exoo, Junnila, and Laihonen determined $M_r^{LD}(P_n)$ for $(3 \le r \le 4)$ and $(r \ge 5$ and $2 \le n \le 7r+3)$. In this thesis, we determine $M_r^{LD}(P_n)$ for $r \ge 5$ and $7r+4 \le n \le 11r+5$.

Keywords: Locating-dominating code, Dominating, Graph.

The study of secure-dominating set of graph products

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If G is a graph and v is a vertex of G, then $N_G(v)$ denotes the neighborhood of v in G and $N_G[v]$ denotes the closed neighborhood of v in G. Given a subset S of $V(G)$, a function A defined on S is called an *attack* on S in G if $A(u) \subseteq N_G(u) - S$ for any $u \in S$ and $A(u) \cap A(v) = \emptyset$ for any distinct vertices u, v. And a function D defined on S is called a *defense* of S if $D(u) \subseteq N_G[u] \cap S$ for any $u \in S$ and $D(u) \cap D(v) = \emptyset$ for any distinct vertices u, v. A nonempty subset S of $V(G)$ is called a *secure set* of G if for each attack A on S, there exists a defense of S such that $|D(u)| \ge |A(u)|$ for any $u \in S$.

One can think the vertices of $A(u)$ as attackers of u and those of $D(u)$ as defenders of u. Each vertex not in S can attack at most one of its neighbor in S. And each vertex in S can defense at most one attack on itself or one attack on its neighbors in S. The attack is thwarted if $|D(u)| \ge |A(u)|$. For a secure set S, each attack on S can be thwarted.

A set S is a *secure-dominating set* of G if S is a secure set of G that is also a dominating set of G. The *secure-dominating number* of G is the minimum cardinality of secure-dominating sets of G.

In this thesis, we obtain some results of secure-dominating sets and secure-dominating numbers of strong product and lexicographic product of graphs.

Keywords: secure-dominating set, secure-dominating number, strong product, lexicographic product.

The Laplacian Spectral Radius of a Graph

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Let $G = (V, E)$ be a simple connected graph with the vertex set V and the edge set E. We have a new sharp bound for the Laplacian spectral radius of G, which improves some known upper bounds.

Keywords: Graph, Laplacian matrix, Laplacian spectral radius.

Error-correcting pooling designs and group testing for consecutive positives

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Pooling designs are standard experimental tools in many biotechnical applications. Many famous pooling designs have been constructed from mathematical structures by "containing relation". Recently, pooling designs constructed by "intersecting relation" have been proposed by Nan and Guo (2010) and Guo and Wang (2011). Constructing by intersecting relation provides much better error-tolerance capabilities. In this thesis, we study the error-tolerance capabilities of pooling designs constructed by intersecting relation from combinatorial structures proposed by

D'yachkov et al. (2007) and Bai et al. (2009). Motivated by application to DNA sequencing, group testing for consecutive positives has been proposed by Balding and Torney(1997) and Colbourn (1999) where n items are linearly ordered and all up to d positive items are consecutive in the order. In this thesis, we study a variation of (k, m, n)-selectors and use this combinatorial object to design a two-stage algorithm for group testing of consecutive positives. Our algorithm takes at most $12 \log_2 \lceil n/d \rceil + 14e + 3d$ tests to identify all positives and its decoding complexity is $O(\frac{n}{d} \log \frac{n}{d} + d)$.

Keywords: Group Testing, Pooling design, Error-tolerance, Consecutive Positives.

Threshold group testing with consecutive positives

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Threshold group testing introduced by Damaschke (2006) is a generalization of classical group testing where a group test yields a positive (negative) outcome if it contains at least u (at most l) positive items, and an arbitrary outcome for otherwise. Motivated by applications to DNA sequencing, group testing with consecutive positives has been proposed by Balding and Torney (1997) and Colbourn (1999) where n items are linearly ordered and all up to d positive items are consecutive in the order. In this thesis, we use threshold-constrained group tests to deal with group testing with consecutive positives. We prove that all positive items can be identified in $\lceil \log_2(\lceil n/u \rceil - 1) \rceil + 2\lceil \log_2(u+2) \rceil + \lceil \log_2(d-u+1) \rceil - 2$ tests sequentially for the gap-free case ($u = l + 1$) while the information-theoretic lower bound is $\lceil \log_2 n(d-u+1) \rceil - 1$ when $n \geq d + u - 2$ and show that the case with a gap ($u > l + 1$) can be dealt with by the subroutines used to conquer the gap-free case. Using a variation of cover-free family we show that the set of positives can be approximately identified in $15 \log_2 \frac{n}{d} + 4d + 71$ group tests nonadaptively and its decoding complexity is $O(\frac{n}{d} \log_2 \frac{n}{d} + ud^2)$.

Keywords: Group testing, Threshold, Consecutive positives, Cover-free families.

Weight Choosability of theta Graphs

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The 1,2,3-conjecture is a problem of edge weight colorability of graphs which was posed by M. Karoński et al in 2004. Further problem of edge weight choosability of graphs was posed by T. Bartnicki et al in 2009. While being solved for some special cases, the two problems are still open nowadays. In this thesis, we use the combinatorial nullstellensatz and the permanent to find some results. We go through the cycles, then discuss the θ-graphs and generalized θ-graphs. The main result of this thesis is to show these graphs are all 3-edge weight choosable.

Keywords: weight choosability, 3-weight choosable, combinatorial nullstellensatz, permanent, cycles, θ-graphs, generalized θ-graphs.

On Antimagic Labeling and Associated Deficiency Problems for Graph Products

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Let $G = (V(G), E(G))$ be a finite simple graph with $p = |V(G)|$ vertices and $q = |E(G)|$ edges. An **antimagic labeling** of G is a bijection from the set of edges to the set of integers $\{1, 2, \cdots, q\}$ such that the vertex sums are pairwise distinct, where the vertex sum at a vertex is the sum of labels of all edges incident to such vertex. Moreover G is called (a, d)**-antimagic** if the vertex sums are $a, a + d, \cdots, a + (|V| - 1)d$ for some positive integers a and d. For the graph G, the (a, d)**-antimagic deficiency** (**antimagic deficiency**, respectively) is defined as the minimum integer k such that the injective edge labeling $f : E(G) \to \{1, 2, \cdots, q+k\}$

is (a, d)-antimagic (antimagic, respectively). This thesis mainly studies antimagic labelings and associated antimagic deficiency problems for certain graph products. In particular, we show the antimagic-ness for strong product of any even regular graph and any regular graph. Also we determine the $(a, 1)$-antimagic deficiency for the Cartesian product of cycles $C_{m_1} \square C_{m_2}$ and the $(a, 1)$-antimagic deficiency for the strong product of cycles $C_{m_1} \boxtimes C_{m_2}$.

Keywords: antimagic labeling, antimagic graph, strong product, Cartesian product.

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21	2014.8.2–3	台灣師範大學數學系	組合數學新苗研討會
20	2013.8.10–11	高雄師範大學數學系	組合數學新苗研討會
19	2012.8.10–12	中山大學應用數學系	圖論及組合研討會暨組合數學新苗研討會
18	2011.8.6–7	淡江大學數學系	組合數學暨新苗研討會
17	2010.8.7–8	中央研究院數學研究所	組合數學新苗研討會
16	2009.8.10–11	中原大學應用數學系	組合數學暨新苗研討會
15	2008.8.11–12	交通大學應用數學系	組合數學暨新苗研討會
14	2007.8.10–11	中山大學應用數學系	組合數學 (新苗) 研討會
13	2006.8.11–12	中國科技大學新竹校區	組合數學研討會
12	2005.8.26–27	東華大學應用數學系	組合數學研討會
11	2004.8.27–28	靜宜大學應用數學系	組合數學研討會
10	2003.9.5–6	台灣大學數學系	組合數學研討會
9	2002.6.28–29	中央大學數學系	組合數學新苗研討會
8	2001.6.16–17	淡江大學數學系	組合數學新苗研討會
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5	1998.6.26–27	中山大學應用數學系	組合數學新苗研討會
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2	1995.6.15–16	交通大學應用數學系	組合數學新苗研討會
1	1990.6.25–26	中央研究院數學研究所	離散數學新苗研討會

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