2015 Combinatorics Workshop
(2015 조합론 학술대회)

CAMP, NIMS, Daejeon, Korea
July 13-16, 2015

Host National Institute for Mathematical Science (NIMS)
Sponsor 2015 NIMS Thematic Program on Combinatorics

2015 Combinatorics Workshop (CW2015)

CAMP, NIMS, Daejeon, Korea

July 13-16, 2015

Contents

Organizing Committee

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- Heesung Shin, Inha University, Korea
- Jiang Zeng, Université Claude Bernard Lyon 1, France

Advisory Committee

- Committee of Mathematics for Information Sciences, The Korean Mathematical Society (Chair: Young Soo Kwon, Yeungnam University)

Timetable

- July 13, Monday
  - 13h30 – 14h00 Registration
  - Session 13A
    - 14h00 – 14h50 Mihyun Kang (Invited Talk 13A-1)
    - 15h00 – 15h25 Sang-il Oum (Talk 13A-2)
    - 15h30 – 16h00 Coffee Break
    - 16h00 – 16h50 Christian Krattenthaler (Invited Talk 13A-3)
- July 14, Tuesday
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    - 10h30 – 10h55 Younjin Kim (Talk 14A-2)
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    - 11h30 – 12h20 Suho Oh (Invited Talk 14A-3)
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  - Session 14B
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    - 15h00 – 16h50 Matthieu Josuat-Vergès (Invited Talk 14B-2)
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- July 15, Wednesday
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  - 12h30 – 14h00 Lunch
  - Session 15B
    - 14h00 – 14h50 James Haglund (Invited Talk 15B-1)
    - 15h00 – 15h25 Per Alexandersson (Talk 15B-2)
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    - 16h00 – 16h50 Byungchan Kim (Invited Talk 15B-3)
    - 17h00 – 17h25 Ringi Kim (Talk 15B-4)
  - 18h00 – 20h00 Dinner
- July 16, Thursday
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    - 10h30 – 10h55 Sang June Lee (Talk 16A-2)
    - 11h00 – 11h30 Coffee Break
    - 11h30 – 12h20 Masao Ishikawa (Invited Talk 16A-3)
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  - Session 16B (Korean)
    - 14h00 – 14h50 Jang Soo Kim (Activity 16B-1)
    - 15h00 – 15h25 Jisu Jeong (Talk 16B-2)
    - 15h30 – 16h20 Sejeong Bang (Invited Talk 16B-3)

General Information

- CAMP Wireless Internet Access
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13A-1 Giant component, the k-core, and branching processes

Mihyun Kang, *Technische Universität Graz, Austria*

Abstract

The k-core, defined as the largest subgraph of minimum degree k, of the random graph $G(n, p)$ has been studied extensively. In a landmark paper Pittel, Wormald and Spencer [JCTB **67** (1996) 111–151] determined the threshold d_k for the appearance of an extensive k-core. Here we derive a multi-type branching process that describes precisely how the k-core is "embedded" into the random graph for any $k \geq 3$ and any fixed average degree $d = np > d_k$. This generalises prior results on, e.g., the internal structure of the k-core.

13A-2 Strongly even-cycle decomposable graphs

Sang-il Oum, *KAIST, Korea*

Abstract

A graph is *strongly even-cycle decomposable* if the edge set of every subdivision with an even number of edges can be partitioned into cycles of even length. We prove that several fundamental composition operations that preserve the property of being Eulerian also yield strongly even-cycle decomposable graphs. As an easy application of our theorems, we give an exact characterization of the set of strongly even-cycle decomposable cographs. This is a joint work with Tony Huynh, Andrew D. King and Maryam Verdian-Rizi.

13A-3 A factorisation theorem for the number of rhombus tilings of a hexagon with triangular holes

Christian Krattenthaler, *Universität Wien, Austria*

Abstract

I shall present a curious factorisation theorem for the number of rhombus tilings of a hexagon with vertical and horizontal symmetry axis, with triangular holes along the latter axis. I shall set this theorem in relation with other factorisation theorems, and discuss some consequences and open questions. This is joint work with Mihai Ciucu.

14A-1 Logarithmic Tree-Numbers for acyclic complexes

Woong Kook, *Seoul National University, Korea*

Abstract

This talk will start with a review of Temperley's tree-number formula for graphs. This formula appears to be less commonly adopted than the matrix-tree theorem in combinatorics despite its advantage in using non-singular matrix when a graph is connected. Specifically, Temperley's formula uses combinatorial Laplacian Δ_0 in dimension zero, and will provide an important model for the high-dimensional tree-numbers defined via incidence matrices (boundary operators).

Generalizing this formula for acyclic cell complexes, we obtain similar relations between the determinants of combinatorial Laplacians Δ_i and the high-dimensional tree numbers k_j. Applying logarithm to these relations reveals an intriguing property about acyclic complexes in general, which will be one of the main results of this talk.

As an application, we will demonstrate how this property together with the spectra of combinatorial Laplacians recovers high-dimensional tree-numbers for various complexes. If time permits, we will discuss the case of matroid complexes and a connection between logarithmic tree-numbers and combinatorial torsion.

14A-2 On Turan-type Problems for Hypergraphs

Younjin Kim, *KAIST, Korea*

Abstract

Extremal Combinatorics aims to determine or estimate the maximum or minimum possible cardinality of a collection of finite objects (sets, graphs, numbers, vectors, etc.) that satisfy certain requirements. The 2012 Abel Prize, regarded as the "Mathematician's Nobel", was awarded to Endre Szemeredi, a 71-year-old Hungarian mathematician, for his contributions to Combinatorics, in particular, Extremal Combinatorics. I am particularly interested in *Turan-type Problems for Hypergraphs*. In this talk, I will prove Erdős-Shelah's Conjecture (1972) and Alon-Babai-Suzuki's Conjecture (1991) related to the turan problem for hypergraph.

14A-3 Generalized Permutohedron and its applications

Suho Oh, *Texas State University, USA*

Abstract

Generalized permutohedron is a collection of polytopes that can be obtained from deforming the facets of a permutohedron. They can be studied using Minkowski sum of simplices and Bipartite graphs due to Postnikov. After going over the basics, I will introduce various results and problems using this theory.

14B-1 Order polytopes, Ehrhart polynomials and Dirichlet series

Frédéric Chapoton, *Université Claude Bernard Lyon 1, France*

Abstract

Partially ordered sets (or posets) are very common in combinatorics. I will recall the classical way to associate with them a polytope, called the order polytope, as introduced by Stanley. It turns out that these polytopes are sometimes Gorenstein polytopes, a notion that generalizes reflexive polytopes. This property has interesting consequences for the counting of integer points in dilated powers of these polytopes, using the well-known theory of Ehrhart polynomials. It turns out that a Dirichlet-like series is involved in this story.

14B-2 Subalgebras of the descent algebra based on alternating runs

Matthieu Josuat-Vergès, *Université de Marne-la-Vallée, France*

Abstract

In a permutation $\sigma(1), \sigma(2), ...$, we can see increasing sequences of consecutive values, alternating with decreasing sequences of consecutive values. We call them alternating sequences and we are interested in the number of such sequences. Various works have been done on the enumerative point of view. We have here an algebraic approach and show that we can define commutative subalgebras of the symmetric group algebra (and more precisely of the descent algebra) by grouping permutations with the same number of alternating sequences. Proofs are partly combinatorial and bijective (existence of subalgebras) and partly algebraic (commutativity).

14B-3 Fully commutative elements in finite and affine Coxeter groups

Frédéric Jouhet, *Université Claude Bernard Lyon 1, France*

Abstract

An element of a Coxeter group is fully commutative (FC) if any two of its reduced decompositions are related by a series of transpositions of adjacent commuting generators. Such elements appear in a natural algebraic context, as they index a linear basis of the (generalized) Temperley–Lieb algebra. By focusing on types A and $\widetilde{A}$, we will explain in this talk how to enumerate FC elements (and involutions) according to their Coxeter length, in finite and affine groups. To this aim, we characterize them in terms of Viennot's heaps of pieces, and compute the desired generating functions through Motzkin-type walks, heaps of monomers and dimers, and integer partitions. In the finite case our work extends the exhaustive enumeration of Stembridge from 1998; the cases of types A and $\widetilde{A}$ simplify and clarify recent results of Barcucci–Del Lungo–Pergola–Pinzani and Hanusa–Jones, respectively. We will show that all our generating functions involve q-Bessel type functions, and that moreover their coefficients form ultimately periodic sequences in all affine types. This talk is based on different recent joint works with R. Biagioli, M. Bousquet-Melou and P. Nadeau.

15A-1 Two new unimodal descent polynomials

Shishuo Fu, *Chongqing University, China*

Abstract

In this talk, we introduce the descent polynomials on two interesting subsets of permutations, namely separable permutations and derangements. We prove that the first is γ-positive, which implies both unimodality and symmetry and the second has the spiral property, a property stronger than unimodality. This is joint work with Zhicong Lin and Jiang Zeng.

15A-2 Proof of Gessel's γ-positivity conjecture

Zhicong Lin, *NIMS, Korea*

Abstract

We prove a conjecture of Gessel, which asserts that the joint distribution of descents and inverse descents on permutations has a fascinating refined γ-positivity.

15A-3 Some congruences involving powers of Legendre polynomials

Victor J. W. Guo, *East China Normal University, China*

Abstract

The Legendre polynomials $P_n(x)$ may be defined as

$$P_n(x) = \sum_{k=0}^{n} \binom{n}{k} \binom{n+k}{k} \left(\frac{x-1}{2}\right)^k.$$

Z.-W. Sun raised the following conjecture.

Conjecture 1. *Let x be an integer and let m and n be positive integers. Then*

$$\sum_{k=0}^{n-1} (2k+1) P_k(2x+1)^m \equiv 0 \pmod{n}. \tag{1}$$

If p is a prime not dividing $x(x+1)$, then

$$\sum_{k=0}^{p-1} (2k+1) P_k(2x+1)^3 \equiv p \left(\frac{-4x-3}{p}\right) \pmod{p^2}, \tag{2}$$

$$\sum_{k=0}^{p-1} (2k+1) P_k(2x+1)^4 \equiv p \pmod{p^2}, \tag{3}$$

where $\left(\frac{\cdot}{p}\right)$ denotes the Legendre symbol.

The congruence (1) in a more general form has been confirmed by Pan. In this talk, we shall prove the other two congruences conjectured by Z.-W.Sun.

15B-1 Combinatorics connected to the Delta Conjecture

James Haglund, *University of Pennsylvania, USA*

Abstract

In 2005 the speaker, Haiman, Loehr, Remmel, and Ulyanov introduced the "shuffle conjecture", which gives a combinatorial prediction for the expansion of the character of Diagonal Harmonics into monomials. The Delta Conjecture is a generalisation of the shuffle conjecture, which has recently been introduced by the speaker, Remmel, and Wilson. We discuss some of the many combinatorial questions inspired by this conjecture.

15B-2 Polynomials defined by tableaux and linear recurrences

Per Alexandersson, *University of Pennsylvania, USA*

Abstract

We provide a framework for showing that under certain conditions, polynomials encoding statistics on certain tableaux, or fillings of diagrams, satisfy a linear recurrence under a natural operation on the shape of the diagram. We prove that several of the classical polynomials from representation theory fall into this category, such as (skew) Schur polynomials, Hall–Littlewood polynomials and dual Grothendieck polynomials.

The motivation behind this is that such recurrences are strongly connected with other nice properties, such as interpretations in terms of lattice points in polytopes and divided difference operators and we provide proofs based on such interpretations as well.

We focus on *key polynomials*, (also known as Demazure characters), and *Demazure atoms*. The key polynomials are natural, non-symmetric generalizations of Schur polynomials and are specializations of the non-symmetric integer form Macdonald polynomials.

Let λ be a fixed diagram shape, (a partition shape, skew shape, composition, *etc.*) and let $P_{k\lambda}(\mathbf{x})$, $k = 1, 2, \ldots$, be a sequence of polynomials which are generating functions of fillings of shape $k\lambda$. For partitions, $k\lambda$ is simply elementwise multiplication by k. We show that under quite general settings, $\{P_{k\lambda}(\mathbf{x})\}_{k=1}^{\infty}$ satisfy a linear recurrence with coefficients in $\mathbb{Q}[\mathbf{x}]$.

There are several reasons why one would be interested in showing that a such sequence satisfies a linear recurrence:

1. To obtain hints about the existence or non-existence of formulas of certain type. For example, the Weyl determinant formula for Schur polynomials implies that the ordinary Schur polynomials satisfy a linear recurrence.
2. To obtain evidence for alternative combinatorial interpretations of the tableaux involved. For example, the skew Schur polynomials can be obtained as lattice points in certain marked order polytopes, called Gelfand–Tsetlin polytopes. Such a polytope interpretation implies the existence of a linear recurrence relation.
3. To prove polynomiality in k of the number of fillings of shape $k\lambda$.
4. To obtain results about asymptotics. For example, one can use such recurrences to give a new combinatorial proof of a classical result on asymptotics of eigenvalues of Toeplitz matrices.

15B-3 On the distribution of rank-type functions

Byungchan Kim, *SeoulTech, Korea*

Abstract

To explain Ramanujan's famous partition function congruences

$$p(5n+4) \equiv 0 \pmod 5$$
$$p(7n+5) \equiv 0 \pmod 7$$
$$p(11n+6) \equiv 0 \pmod{11}$$

F. Dyson introduced partition ranks by the difference between the largest part and the number of parts. This rank function not only provides a combinatorial explanation for partition congruences but also becomes a prototype of mock theta functions (or mock modular forms). More recently, in a relation with partial theta functions (or quantum modular forms), ranks for unimodal sequences have been studied. Here, by unimodal sequences, we mean an integer sequence has a peak in the sequence. For example, $u(n)$ denote the number of unimodal sequences of the form

$$a_1 \le a_2 \le \cdots \le a_r \le \overline{c} \ge b_1 \ge b_2 \ge \cdots \ge b_s$$

with weight $n = c + \sum_{j=1}^{r} a_j + \sum_{j=1}^{s} b_j$, and we define its rank by $r - s$. Though generating functions of these ranks are already appears in Ramanujan's works and there have been much advances in understanding a general structure of this type of functions, their distributions are still mysterious. In this talk, we are going to review some progress toward unmodal property of these ranks.

15B-4 Tree-chromatic number is not equal to path-chromatic number

Ringi Kim, *Princeton University, USA*

Abstract

For a graph G and a tree-decomposition $(T, \mathcal{B})$ of G, the *chromatic number* of $(T, \mathcal{B})$ is the maximum of $\chi(G[B])$, taken over all bags $B \in \mathcal{B}$. The *tree-chromatic number* of G is the minimum chromatic number of all tree-decompositions $(T, \mathcal{B})$ of G. The *path-chromatic number* of G is defined analogously. In this talk, we introduce an operation that always increases the path-chromatic number of a graph. As an easy corollary of our construction, we obtain an infinite family of graphs whose path-chromatic number and tree-chromatic number are different. Our results also imply that the path-chromatic numbers of the Mycielski graphs are unbounded.

16A-1 On the existence of generalized parking spaces for complex reflection groups

Soichi Okada, *Nagoya University, Japan*

Abstract

Let W be a finite irreducible complex reflection group acting on a complex vector space V. For a positive integer k, we consider a class function φ_k and its q-analogue $\widetilde{\varphi}_k$ on W given by

$$\varphi_k(w) = k^{\dim V^w}, \quad \widetilde{\varphi}_k(w) = \frac{\det_V(1 - q^k w)}{\det_V(1 - qw)} \quad (w \in W),$$

where V^w is the fixed-point subspace of w. In this talk, we give a complete answer to the question when φ_k (resp. $\widetilde{\varphi}_k$) is the character (resp. the graded character) of a representation (resp. a graded representation) of W. Such a representation can be regarded as a generalization of the permutation representation of the symmetric group S_n on classical parking functions ($W = S_n$ and $k = n + 1$).

In the course of our proof for the symmetric group, we find the greatest common divisor of the special values $s_\lambda(1^k)$ (resp. the principal specialization $s_\lambda(1, q, \dots, q^{k-1})$) of Schur functions, where λ runs over all partitions of n. And we propose a conjecture on the unimodality of the coefficients of certain polynomials obtained as a quotient of the principal specializations.

This talk is based on a joint work with Yusuke ITO.

16A-2 On a phase transition of the random intersection graph: Supercritical region

Sang June Lee, *Duksung Women's University, Korea*

Abstract

When each vertex is assigned a set, the intersection graph generated by the sets is the graph in which two distinct vertices are joined by an edge if and only if their assigned sets have a nonempty intersection. An interval graph is an intersection graph generated by intervals in the real line. A chordal graph can be considered as an intersection graph generated by subtrees of a tree. In 1999, Karoński, Scheinerman and Singer-Cohen [Combin Probab Comput 8 (1999), 131–159] introduced a random intersection graph by taking random assigned sets. The random intersection graph $G(n, m; p)$ has n vertices and their assigned sets are chosen to be i.i.d. random subsets of a fixed set M of size m where each element of M belongs to each random subset with probability p, independently of all other elements in M. Fill, Scheinerman and Singer-Cohen [Random Struct Algorithms 16 (2000), 156–176] showed that the total variation between the random graph $G(n, m; p)$ and the Erd"os-Rényi graph $G(n, \hat{p})$ tends to 0 if $m = n^{\alpha}$, $\alpha > 6$, where $\hat{p}$ is chosen so that the expected numbers of edges in the two graphs are the same. In this paper, it is proved that the total variation still tends to 0 whenever $m \gg n^4$. We believe that this is the best possible. This is joint work with Jeong Han Kim and Joohan Na.

16A-3 The domino tilings of Aztec rectangles with consecutive holes and the Gauss hypergeometric series

Masao Ishikawa, *University of the Ryukyus, Japan*

Abstract

It is famous that the number of domino tilings of an Aztec diamond is 2 to the n choose 2. We study the number of domino tilings of an Aztec rectangle with even number of consecutive holes in a line and we obtain a formula which express the number of such domino tilings by a product of a similar power of 2, a nice product and a polynomial of the coordinates of the holes in line. We will find a formula which expresses this polynomial as a determinant of terminating Gauss hypergeometric series and show that this polynomial possesses interesting properties. First we use the Lindstrom-Gessel-Viennot theorem to enumerate the domino tilings of an Aztec rectangle with consecutive holes and obtain a determinant whose entries are generalized large Schroder numbers. Then we consider a more general determinant whose entries are the moments of the Laurent biorthogonal polynomials, which enable us to apply the Desnanot-Jacobi adjoint matrix theorem. This general determinant reduces to the case q=t=1 in Kamioka's result if we have no hole, i.e., the Aztec diamond case. Then the evaluation of the determinant reduces to a quadratic relation of the above polynomials. This project is still a work in progress and we believe that we are very close to the complete proof. This is a joint work with Fumihiko Nakano, Takzo Sadahiro and Hiroyuki Tagawa.

16B-1 Let's learn how to Juggle!!!

Jang Soo Kim, *Sungkyunkwan Unviersity, Korea*

16B-2 Constructive algorithm for path-width of matroids

Jisu Jeong, *KAIST, Korea*

Abstract

We present a fixed-parameter tractable algorithm to construct a path-decomposition of width at most k, if it exists, for an input $\mathbb{F}$-represented matroid with a parameter k. Our approach is based on dynamic-programming combined with the idea developed by Bodlaender and Kloks (*Efficient and constructive algorithms for the pathwidth and treewidth of graphs*, J. Algorithm, 1996) for their work on path-width and tree-width of graphs.

It was previously known that a fixed-parameter tractable algorithm exists for the decision version of the problem; a theorem by Geelen, Gerards, and Whittle (*Branch-width and well-quasi-ordering in matroids and graphs*, J. Combin. Theory Ser. B, 2002) implies that for each fixed finite field $\mathbb{F}$, there are finitely many forbidden minors for the class of $\mathbb{F}$-representable matroids of path-width at most k. An algorithm by Hliněný (*Branch-width, parse trees, and monadic second-order logic for matroids*, J. Comb. Theory Ser. B, 2006) can now be used to detect a minor in an input $\mathbb{F}$-represented matroid of bounded branch-width. However, this indirect approach would not produce an actual path-decomposition even if the compete list of forbidden minors were known. Our algorithm is the first one to construct such a path-decomposition if it exists and does not use the finiteness of forbidden minors.

16B-3 On distance-regular graphs with diameter three and smallest eigenvalue in $(-3, -2)$

Sejeong Bang, *Yeungnam University, Korea*

Abstract

A connected graph has smallest eigenvalue at most -1 with equality if and only if the graph is complete. For connected regular graphs with smallest eigenvalue at least -2, it was shown by P.J. Cameron et al. (1976) that either it is a line graph, a cocktail party graph, or the number of vertices is at most 28. In this talk, we classify distance-regular graphs with diameter three and smallest eigenvalue in $(-3, -2)$. As an application, some feasible intersection arrays for distance-regular graphs are ruled out. This is a joint work with J. Koolen.

Memo

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