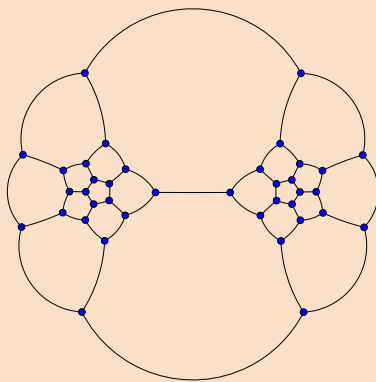


6<sup>th</sup> Croatian Combinatorial Days  
Zagreb, September 2026



Book of Abstracts



## IMPRESSUM

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## Contributed talks

### New constructions and bounds for finite models of Hilbert's incidence geometry

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This talk studies finite models of Hilbert's incidence axioms, with emphasis on new constructions and on the asymptotic growth of the number of such models. In previous work, several natural families of models were described and used to obtain a general lower bound on the number  $\text{HilbInc}(n)$  of nonisomorphic models with  $n$  points; for almost all values of  $n$ , this bound was only linear in  $n$ . Here we introduce two further constructions: affine-plane-models and projectively derived models. We compare these families with the previously known ones, determine the overlaps, and show that the family of derived models gives a much stronger general lower bound. We also give a general upper bound, which altogether substantially improves the picture of how  $\text{HilbInc}(n)$  grows.

This is a joint work with Bojan Bašić.



# Productivity Measures and Extremal Topologies in Communication Networks

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Communication networks can be represented by graphs in which vertices exchange information and shortest-path distances determine the cost and flow of communication. We discuss several graph-based measures of productivity, including transmission, betweenness centrality, networkness and network surplus. A key ingredient is the assumption that the amount of communication between two vertices decreases with their distance. We consider two classes of distancedependent models: polynomial and exponential decay of communication. For these measures, we describe how network topology influences productivity and present extremal results identifying graph structures and vertices that maximize or minimize the corresponding descriptors.



## Orderly generation of Cayley sum graphs

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Given a group  $G$  and a subset  $S \subseteq G$ , the Cayley sum graph has vertex set  $G$ , where vertices  $x, y \in G$  are adjacent if and only if  $x + y \in S$ . This ‘additive variant’ of Cayley graphs has been studied in several contexts, including applications in coding theory. We present an efficient program for generating Cayley sum graphs based on orderly generation. The algorithm uses the natural group action on connection sets to generate one representative from each orbit. The resulting graphs are then canonically labelled to identify any remaining graph isomorphisms.

Our motivation originates in Hückel molecular orbital theory. We study UBN graphs, defined as graphs in which all vertices have the same Coulson bond number. As we will show, every Cayley sum graph is a UBN graph, which makes this class of graphs of interest in chemical graph theory.



## This should not be an impossible hat puzzle

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We begin with a harmless guessing game involving three prisoners and numbered hats. The first version is easy enough to solve over drinks. A seemingly slight modification is harder. Yet, the rules barely change, the question remains elementary to state, and nothing in the modification suggests that the problem suddenly acquires a mathematical character wildly disproportionate to its innocent appearance.

Be warned: when we get to that second puzzle, premature guesses at the answer are at your own risk. The aim of the talk is to maximize the number of people in the audience who find themselves wondering: “Surely that *cannot be* what this puzzle is about!?”

No hats will be harmed. Expectations may be.



## $[k]$ -Roman Domination on Cylindrical Grids

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Roman domination models the allocation of defensive resources in a network by assigning protection levels to vertices. The  $[k]$ -Roman framework unifies the classical Roman, double Roman, triple Roman, and higher-order variants. A function  $f: V(G) \rightarrow \{0, \dots, k+1\}$  is a  $[k]$ -Roman dominating function if every vertex  $v$  with  $f(v) < k$  satisfies

$$f(N[v]) \geq k + |\{u \in N(v) : f(u) > 0\}|.$$

We study the minimum possible weight  $\gamma_{[k]R}$  of such a function on cylindrical grids  $C_m \square P_n$ . We first establish the density-type lower bound and show how equality in the underlying local estimate is controlled by efficient domination. We then construct explicit periodic labelings for small fixed circumferences  $m \in \{3, \dots, 9\}$ . Together with uniform ceiling-type assignments and packing-based refinements, these constructions yield competing upper bounds whose relative strength depends on  $k$  and  $n$ . Finally, we extend the periodic constructions to circumferences that are multiples of a small base value and obtain bounds for arbitrary  $m$  from its residue class modulo 5. The special case  $k = 2$  yields new upper bounds for double Roman domination. The results illustrate how local domination constraints, efficient dominating sets, and packing structures interact to determine the asymptotic density of optimal labelings on product graphs.

This is a joint work with prof. Janez Žerovnik.



## More on the Builder-Blocker mutual-visibility game

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In our work, we focus on a game version of the mutual-visibility problem on a graph. Two players, Builder and Blocker, alternately select an unplayed vertex on a graph to form a mutual-visibility set. Builder aims to have a mutual-visibility set as large as possible, while the goal of Blocker is the opposite. The game ends when the mutual-visibility set is maximal, and the number of selected vertices in the set when both players play optimally is the Builder-Blocker mutual-visibility game number. We determine graphs which have this number as two in the game started by Builder. We also study the game on thin grids and block graphs.

This is a joint work with Prof. Sandi Klavžar.



## On the nonlocal multiset dimension of graphs

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Given a connected graph  $G$  and a set  $S = \{s_1, \dots, s_k\} \subseteq V(G)$ , the *multiset representation* of a vertex  $x \in V(G)$  with respect to  $S$  is the multiset  $m(x|S) = \{\{d(x, s_1), \dots, d(x, s_k)\}\}$ , where  $d(x, s_i)$  is the distance between  $x$  and  $s_i$ . A set  $S$  is a *multiset resolving set* of  $G$  if  $m(x|S) \neq m(y|S)$  for all distinct  $x, y \in V(G)$ . The *multiset dimension* of  $G$  is the minimum cardinality of a multiset resolving set of  $G$ . In this work, we introduce and study the *nonlocal multiset dimension* of  $G$ , denoted by  $\text{md}_{\text{nl}}(G)$ , which requires distinguishing only nonadjacent pairs of vertices by their multiset representations. We characterize graphs  $G$  with  $\text{md}_{\text{nl}}(G) \in \{1, 2\}$ , establish some properties for trees, determine exact values for several well-known graph families, and propose several open problems.

The speaker has been partially supported by the Spanish Ministry of Science and Innovation through the grant PID2023-146643NB-I00.

This is a joint work with Sandi Klavžar, Dorota Kuziak and Ismael G. Yero.



# The area generating functions for left-lifted and left-grounded column-convex polyominoes

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A *cell* is a unit square whose vertices lie in the  $xy$ -plane and have integer coordinates. A *column* is a one-unit-wide, finite and connected union of cells. A *column-convex polyomino* is a finite, edge-connected union of columns, where no two columns have the same horizontal projection. A column-convex polyomino is *left-lifted* (respectively *left-grounded*) if the minimum ordinate of the leftmost column is greater or equal (respectively less or equal) than the minimum ordinate of any other column. By convention, two column-

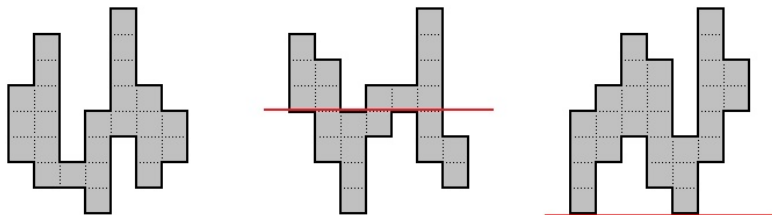


**Figure 1:** From left to right: A column-convex polyomino, a left-lifted column-convex polyomino and a left-grounded column-convex polyomino.

convex polyominoes are different if and only if there does not exist a translation that maps one of them to the other. Let  $S$  be a family of column-convex polyominoes. By the area generating function of  $S$ , we mean the formal power series  $\sum_{i,j=1}^{\infty} a_{ij} q^i x^j$ , where  $a_{ij}$  is the cardinality of the set  $\{P \in S : P \text{ has } i \text{ cells and } j \text{ columns}\}$ .

The area generating function for all column-convex polyominoes is well-known (it is a rational function). On the other hand, left-lifted and left-grounded column-convex polyominoes have not been studied before now. Hence their area generating functions are new. The area gf of the left-lifted model is algebraic and satisfies a quadratic equation. The area gf of the left-grounded model is a complicated  $q$ -series.



## Symmetric Chemical Reaction Networks

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A chemical reaction network (CRN) consists of a set of species  $X_i$ , a set of complexes  $A_j = \sum_i a_{j,i} X_i$  and a set of reactions  $A \rightarrow B$  for complexes  $A \neq B$  with some positive reaction parameter  $\kappa_{A,B}$ . We can view CRNs as directed, weighted graphs. From a CRN, differential equations, the mass action ODE, can be obtained describing the concentration of the species over time. Many CRNs admit symmetries that can be exploited in their analysis. In particular, we show that symmetric networks yield equivariant mass-action ODEs and that the converse is true in a weaker form. This can be used when the computing corresponding steady states.

This is a joint work with Sebastian Debus, and Nils Gubela.



## On the Energy of Self-Looped Graphs

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Let  $G$  be a finite simple graph with the set of vertices  $V(G)$ ,  $|V(G)| = n$ , and the set of edges  $E(G)$ ,  $|E(G)| = m$ . The graph  $G$  will be considered by means of the eigenvalues of the adjacency matrix  $A = A(G)$  and the Laplacian matrix  $L = L(G) = D(G) - A(G)$ , where  $D = D(G)$  is the diagonal matrix of vertex degrees. The eigenvalues of  $G$  with respect to the adjacency matrix will be denoted by  $\lambda_i(G)$ , while with respect to the Laplacian matrix by  $\nu_i(G)$ ,  $1 \leq i \leq n$ .

Let  $\emptyset \neq S \subseteq V(G)$ , where  $|S| = \sigma$ . The *self-loop graph*  $G_S$  of  $G$  at  $S$  is the graph of order  $n$  obtained from  $G$  by attaching a self-loop at each vertex from the set  $S$ . The adjacency matrix  $A(G_S)$  of  $G_S$  takes the form  $A(G_S) = A(G) + \mathfrak{I}_S$ , where  $\mathfrak{I}_S$  is the diagonal matrix with exactly  $\sigma$  ones on the main diagonal corresponding to  $S$  and all other entries equal to zero. The adjacency eigenvalues of  $G_S$  are denoted as  $\lambda_i(G_S)$ ,  $1 \leq i \leq n$ .

The *energy*  $\mathcal{E}(G) = \sum_{i=1}^n |\lambda_i(G)|$  of a graph  $G$  is a well-established and extensively studied graph invariant. This definition is actually based on the difference of the adjacency eigenvalues of the graph and their arithmetic mean, which also served as the main concept in defining a large number of graph energies with respect to the various graph matrices, such as the *Laplacian energy*  $\mathcal{LE}(G) = \sum_{i=1}^n \left| \nu_i(G) - \frac{2m}{n} \right|$ .

The *energy*  $\mathcal{E}(G_S) = \sum_{i=1}^n \left| \lambda_i(G_S) - \frac{\sigma}{n} \right|$  of the *self-loop graph*  $G_S$  of the given graph  $G$ , was introduced in [4], where the first conjecture comparing the values of the energy of a self-looped graph and the energy of its underlying graph was posed. This conjecture was disproved very quickly after it was published [5] by considering the coalescence of the complete graph  $K_n$ ,  $n \geq 4$ , and the two-vertex graph  $K_2$ . Based on the study of bipartite graphs, the mentioned conjecture has obtained its modified version [1]. The authors of [7] confirmed the modified conjecture by considering an independent set of graph vertices, while the authors of [3] verified it in the set of certain complete multipartite graphs.

Two (self-loop) graphs with the same number of vertices are said to be *M-equienenergetic* if they have the same energy regarding some graph matrix  $M$ . In analogy with the problems which study simple graphs, the problem of finding



equienergetic graphs with self-loops was put forward in [4] and [7] where the first examples of  $A$ -equienergetic self-loop graphs are exposed. Certain pairs of  $A$ -equienergetic graphs with self-loops, among which there are those whose underlying graphs are  $L$ -equienergetic will be presented. In finding such pairs, the authors of [3] used the concept proposed by Consonni and Todeschini [2], which is further employed by Peña and Rada [6], and which is based on the consideration of the *inner* and the *outer energy* of a graph.

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This is a joint work with Jing Gao.



# Counting Planetary Conjunctions

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In our previous work, using JPL Horizons Ephemeris system, [1], we collected data for apparent positions of outer planets Jupiter, Saturn, Uranus and Neptune, [2]. Using ecliptic longitudes for planetary positions in the period 1600 - 2200 we found 233 conjunction events of outer planets, for the six pairs of planets.

In this talk our objects of interest are sequences related to these events such as sequence of time gaps between two conjunctions and sequence of conjunction planet pairs and discuss how they are connected to continuous-time dynamic systems by looking at the idealized system of points rotating on a circle, [3].

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## Schur-convexity of functions originating from Newton-Cotes quadrature rules

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The motivation for the research we report comes from a result of I. Franjić and J. Pečarić (“Schur-convexity and the Simpson formula,” Appl. Math. Lett. 24 (2011), 1565–1568). For  $f : I \rightarrow \mathbb{R}$ ,  $f \in C^4(I)$ , they defined the function  $S_1 : I^2 \rightarrow \mathbb{R}$  by

$$S_1(x, y) = \begin{cases} \frac{1}{6} \left( f(x) + 4f\left(\frac{x+y}{2}\right) + f(y) \right) - \frac{1}{y-x} \int_x^y f(t) dt, & x \neq y, \\ 0, & x = y. \end{cases}$$

As the authors prove, its Schur-convexity is equivalent to 4-convexity and non-negativity. We show that the Schur-convexity of several other functions defined via error terms for Newton–Cotes quadrature rules of both closed and open types is also equivalent to their nonnegativity. This holds, in particular, for Simpson’s 3/8 rule and for some functions arising from Hermite–Hadamard inequalities. One of the latter is the function  $H(x, y)$  defined by

$$H(x, y) = \begin{cases} \frac{1}{y-x} \int_x^y f(t) dt - \frac{1}{2} \left[ f\left(\frac{3x+y}{4}\right) + f\left(\frac{x+3y}{4}\right) \right], & x \neq y, \\ 0, & x = y. \end{cases}$$

N. Safaei and A. Barani (“Schur-convexity for some differences of convex functions,” Rocky Mt. J. Math. 51 (1) (2021), 273–281) investigated its Schur-convexity. Clearly, the Schur-convexity of  $H(x, y)$  implies the convexity of  $f$ . If  $f \in C^4(I)$  is convex and 4-convex, then  $H(x, y)$  is Schur-convex. The authors leave open whether the assumption that  $f$  is 4-convex can be omitted. We resolve this in the affirmative and prove that  $H(x, y)$  is Schur-convex if and only if  $f \in C^2(I)$  is convex.

This is a joint work with Tomislav Došlić.



## Maximum intersecting families of blocks in Steiner 2-designs

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A family  $\mathcal{F}$  of  $k$ -subsets of a  $v$ -element set  $X$  is *intersecting* if any two members of  $\mathcal{F}$  have non-empty intersection. By the celebrated Erdős-Ko-Rado theorem,  $|\mathcal{F}| \leq \binom{v-1}{k-1}$  provided that  $2k \leq v$ . Furthermore, if  $2k < v$ , equality holds only for canonical intersecting families, i.e. families consisting of all  $k$ -subsets containing a fixed element of  $X$ .

We consider the analogous problem for a Steiner 2- $(v, k, 1)$  design  $\mathcal{D} = (X, \mathcal{B})$ . Provided that  $k^2 - k + 1 < v$ , the size of an intersecting family of blocks  $\mathcal{F} \subseteq \mathcal{B}$  is bounded by  $|\mathcal{F}| \leq \frac{v-1}{k-1}$ , the number of blocks through a fixed point. However, there are cases with non-canonical maximum intersecting families, notably when  $\mathcal{D}$  is an affine plane or a Steiner design with the same parameters as the projective space  $\text{PG}_1(3, q)$ . We present sporadic examples with parameters 2- $(66, 6, 1)$  and 2- $(120, 8, 1)$ , and discuss attempts to generalize them to infinite families.

This is a joint work with Sam Adriaensen, Sergey Goryainov and Elena V. Konstantinova.



## Proper cycles in edge-colored graphs

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A cycle in an edge-colored graph is called proper if any two adjacent edges of the cycle have different colors. In this talk we will survey the results on proper cycles in edge-colored graphs. The results are classified into edge-colored general graphs and edge-colored complete graphs. Some open problems are also presented for further study.



## Combinatorial Problems from Mathematical Competitions on Topological Surfaces

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Many combinatorial problems appearing in mathematical competitions are formulated on finite planar configurations, where the geometry of the underlying grid plays a central role in the existence and structure of their solutions. In this talk, we investigate how selected classes of such problems change when their underlying configurations are considered on different topological surfaces.

We focus primarily on problems related to tilings and discrete configurations on square grids. By identifying opposite boundary components, the same finite configuration can be transferred from the plane to surfaces such as the cylinder, torus, and Klein bottle. This change of topology may alter both the existence of solutions and the structure of the corresponding solution space.

For selected examples, we examine equivalence classes of configurations under elementary local transformations and investigate their combinatorial and topological invariants. In particular, we consider how homological properties and the topology of the ambient surface constrain possible configurations.

The aim is to establish a connection between classical combinatorial problems from mathematical competitions and topological combinatorics, showing that seemingly elementary problems can exhibit substantially different behaviour when viewed on non-planar surfaces.



## Exploring the Distance Structure of (5, 0)-Nanotubes

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We investigate the distance structure of closed (5,0)-nanotubes. Exploiting their layered structure and symmetries, we determine the eccentricities and distance partition vectors of all vertices. These results provide a unified framework for deriving several distance-based topological indices, including the Wiener and hyper-Wiener indices and their generalizations. Our approach demonstrates how the highly regular structure of nanotubical graphs can be used to obtain explicit formulas for global distance-based invariants and can be adapted to related families of nanotubes.

This is a joint work with Vesna Andova, Martin Knor and Riste Škrekovski.



## On 2- $Y$ -homogeneous $(Y, Y')$ -distance-biregular graphs with $D = 4$

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Distance-biregular graphs form a natural bipartite generalization of distance-regular graphs. In this talk, we focus on the class of 2- $Y$ -homogeneous distance-biregular graphs. We present the recent results together with the classification of such graphs with diameter  $D = 4$ .

This is a joint work with Blas Fernández, Safet Penjić and Sanja Rukavina.



## Extriangles and Equal-Area Trapezoids

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In this paper we consider a geometric construction based on an arbitrary initial triangle and successive outward constructions of squares and quadrilaterals. The three outer quadrilaterals in the first configuration have equal areas, each being five times the area of the initial triangle. For subsequent configurations, we establish that the outer quadrilaterals are trapezoids and derive a recurrence relation governing their areas. The obtained recurrence reveals an intrinsic connection between the recursive geometric construction, area relations, and integer sequences.

This is a joint work with Petra Marija De Micheli Vitturi.



## On Restricted King Walks On Colorful Chess Board

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We consider a colorful chess board with dimensions  $(n+1) \times (n+1)$ , where every unit square has the coordinate  $(x, y)$ , where  $0 \leq x, y \leq n$  and  $x, y$ , and  $n$  are non-negative integers. We say that an unit square has the black color if the sum of his coordinates is even, otherwise the unit square has the white color. Let  $K_{n,w}$  denote an non-negative integer that represents the total number of king walks on colorful chess board such that king visits exactly  $w$  white unit squares by moving from  $(0, 0)$  to  $(n, n)$  using only horizontal  $(1, 0)$ , vertical  $(0, 1)$ , and diagonal steps  $(1, 1)$ , where  $0 \leq w \leq n$ . Using a combinatorial argument and a formula for combinations with repetitions twice, we present an exact closed formula for the number  $K_{n,w}$ . We consider a new triangle whose elements are numbers  $K_{n,w}$ . We give a new representation for central Delannoy numbers as sums of rows of this triangle. Finally, we confirm that this formula is true using one known formula with binomial coefficients.



## LDPC codes from Deza digraphs

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In this talk, we present a construction of LDPC codes obtained from Deza digraphs with parameters  $(n, k, 0, 1)$ . The obtained LDPC codes have no cycles of length four in the Tanner graphs corresponding to the adjacency matrices of the Deza digraphs as parity-check matrices. We describe how LDPC codes can be obtained by applying the Cartesian product of certain Deza digraphs, and the Kronecker product of an adjacency matrix of a Deza digraph with parameters  $(n, k, 0, 1)$  or  $(n, k, 1, 1)$  and a permutation matrix. We also use several other combinatorial objects in the construction of LDPC codes.

This is a joint work with Marina Šimac.



## On Near-Extremal Type I $\mathbb{Z}_4$ -Codes of Length 48

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Self-dual codes over  $\mathbb{Z}_4$  form an important class of codes with connections to binary codes, nonlinear codes, and extremal problems in coding theory. In this talk, we focus on Type I self-dual  $\mathbb{Z}_4$ -codes of length 48 and the problem of constructing codes with large minimum Euclidean weight. For this length, the extremal bound cannot be attained in the Type I case, which naturally leads to the study of near-extremal codes. We discuss a construction approach based on suitable doubly even binary residue codes and a neighborhood search method for finding self-dual  $\mathbb{Z}_4$ -lifts. The talk will present the main ideas of the construction and the resulting new examples of near-extremal Type I  $\mathbb{Z}_4$ -codes of length 48.

This is a joint work with Sanja Rukavina.



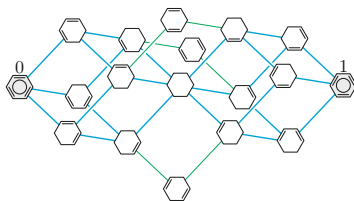
## From tilings and compositions to Fibonacci cubes and matchings

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The tilings of a  $(1 \times n)$ -board with squares and dominoes and the compositions of a positive integer  $n$  both admit a natural coding by binary strings of length  $n - 1$ . Let two objects be adjacent if one arises from the other by splitting a part into two parts or by merging two consecutive parts, that is, if their codes differ in one digit. Every family then becomes the vertex set of a graph: the graph of all compositions of  $n$  is the  $(n - 1)$ -dimensional hypercube, admitting parts 1 and 2 only gives the Fibonacci cube, and a cyclic restriction gives the Lucas cube. Our main example is the family of “odd part even multiplicity” compositions of Munagi and Sellers, for whose graphs we determine recurrence relations for the numbers of vertices and of edges. Finally, since Fibonacci cubes are the resonance graphs of fibonacenes, the same structures describe the perfect matchings of zigzag hexagonal chains, and the graph of *all* matchings of such a chain turns out to be a subgraph of a higher-dimensional hypercube mosaic.



The graph of all matchings of a hexagonal chain

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# On hypersequences of an arbitrary sequence and their weighted sums I+II

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We study the hypersequences  $(a_n^{(r)})_{n \in \mathbb{N}_0}$ ,  $r \in \mathbb{N}_0$ , of an arbitrary sequence (of real or complex numbers)  $(a_n)_{n \in \mathbb{N}_0}$  defined recursively for all  $n, r \in \mathbb{N}_0$  as

$$a_n^{(0)} := a_n, \quad a_n^{(r)} := \sum_{k=0}^n a_k^{(r-1)}, \quad r \geq 1.$$

In the first part, we apply the results to the constant sequence  $a_n = 1$ ,  $n \geq 0$ , the Fibonacci sequence and the Lucas sequence and obtain some new results on the hyperfibonacci and hyperlucas numbers. After that we investigate weighted sums of the type  $t_\ell^{(r)}(n) := \sum_{k=0}^n k^\ell a_k^{(r)}$ ,  $\ell \in \mathbb{N}_0$ , and derive a recurrence relation and its solution. This solution is given by the formula  $t_\ell^{(r)}(n) = \sum_{m=0}^\ell c_{\ell,m}(n) a_n^{(r+m+1)}$ , where  $c_{\ell,m}(n) := \sum_{k=0}^m (-1)^k \binom{m}{k} (k+n+1)^\ell$  and the infinite lower diagonal matrix  $C(n) := (c_{\ell,m}(n))_{\ell,m \in \mathbb{N}_0}$  does not depend on  $r$ .

In the second part, we derive an inverse relation for  $r = 0$ , i.e., we express the hypersequences  $a_n^{(j+1)}$ ,  $j \in \mathbb{N}_0$ , in terms of the weighted sums  $t_j^{(0)}(n)$ ,  $j \in \mathbb{N}_0$ . In proving this theorem, we obtain a matrix  $B(n)$ , whose entries are a signed transformation of the entries of  $E(n)$ , a matrix of specializations of elementary symmetric polynomials. This theorem enables us to determine the inverses of both  $C(n)$  and  $B(n)$ . Furthermore, we present some properties of the entries of  $B(n)$  and  $E(n)$ . In conclusion, we note that the recurrences satisfied by the entries of  $B(n)$ ,  $E(n)$ , and  $C(n)$  are special cases of a general linear two-parameter recurrence problem first posed by Graham, Knuth, and Patashnik.



## Real and Schneider's $p$ -adic continued fractions of rational numbers

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Fix a prime  $p$ . We consider positive rational  $p$ -adic units with finite Schneider's  $p$ -adic continued fraction expansion and compare this expansion with the ordinary real continued fraction expansion. We construct examples showing that the lengths of the two expansions may behave in essentially different ways: one of them may remain bounded while the other grows, and there are also families in which both grow logarithmically with the height. We also study convergents appearing in both the ordinary and Schneider's expansions. For rational numbers of height at most  $H$ , we prove a general upper bound for the maximal possible number of common convergents and a lower bound of order  $\log \log H$ . For  $p = 2$ , we also obtain a sharper bound.



# A Combinatorial Bridge Between Graphical Zonotopes and Graph-Associahedra

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For a simple graph  $\Gamma$  on  $n$  vertices, the Stanley chromatic symmetric function, see [1], admits a geometric interpretation as an enumerator of lattice points in normal cones of vertices of the graphical zonotope. It further decomposes as a sum of quasisymmetric generating functions of  $P$ -partitions associated to acyclic orientations of  $\Gamma$ .

In contrast, the chromatic quasisymmetric function, see [2], is realized in the setting of the graph-associahedron, where it decomposes via  $P$ -partitions associated to  $B$ -trees.

From this viewpoint, we introduce a family of generalized permutohedra interpolating between these two constructions. More precisely, in [3] a sequence of generalized permutohedra:

$$Q_{\Gamma,1}, Q_{\Gamma,2}, \dots, Q_{\Gamma,n-1}$$

is considered, where each polytope  $Q_{\Gamma,m}$  is defined as a Minkowski sum of simplices indexed by connected vertex subsets of  $\Gamma$  of size at most  $m+1$ . The extremal cases recover the graphical zonotope  $Q_{\Gamma,1}$  and the graph-associahedron  $Q_{\Gamma,n-1}$ .

This sequence induces a corresponding family of quasisymmetric functions obtained via lattice points in normal cones of vertices of  $Q_{\Gamma,m}$ , thereby connecting the Stanley chromatic symmetric function with the chromatic quasisymmetric function.

We show that this interpolation is reflected at the level of combinatorial invariants: each function admits a decomposition into quasisymmetric generating functions of  $P$ -partitions associated to  $H$ -posets, which provide a common generalization of acyclic orientations and  $B$ -trees.

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## Twist polynomial interpolation for binary delta-matroids

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Gross, Mansour and Tucker introduced the partial-dual polynomial of a ribbon graph and asked under what conditions such a polynomial is even-interpolating, odd-interpolating, or both. In this talk, we provide an answer to this open problem. Using the framework of delta-matroids, we prove that the twist polynomial of any binary delta-matroid is either an even polynomial, an odd polynomial, or both even-interpolating and odd-interpolating. Applying this to ribbon graphs, we deduce that the partial-dual polynomial of any ribbon graph satisfies the same conclusion.

This is a joint work with Zhao Zhao.



## On 1-limited and $(1, 2)$ -domination in cubic graphs

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A dominating set  $D$  of a graph is called 1-limited if every vertex of  $D$  has at most one neighbor outside  $D$ , while a  $(1, 2)$ -dominating set is a dominating set in which every vertex of the set has at least two neighbors within the set. These two notions coincide on cubic graphs. We prove that the decision problem 1-LIMITED DOMINATING SET is NP-complete even when restricted to 2-connected planar cubic graphs, thereby completing the known complexity results for  $k$ -LIMITED DOMINATING SET for all fixed positive integers  $k$ . We also determine the exact 1-limited domination number of Flower snarks, Goldberg snarks and generalized Blanuša snarks. This provides further infinite families of cubic graphs supporting several open conjectures and proposed bounds concerning  $(1, 2)$ -domination and induced cycles.

This is a joint work with Gordana Radić and Aleksandra Tepeh.



## 2-rainbow independent domination in complementary prisms

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A function  $f$  that assigns values from the set  $\{0, 1, \dots, k\}$  to the vertices of a graph  $G$  is called a  $k$ -rainbow independent dominating function if, for each  $i \in \{1, 2, \dots, k\}$ , the vertices assigned the value  $i$  form an independent set, and every vertex assigned the value 0 has at least one neighbor in each of these independent sets. The  $k$ -rainbow independent domination number of  $G$ , denoted by  $\gamma_{rik}(G)$ , is the minimum number of vertices assigned a nonzero value.

In this talk, we focus on 2-rainbow independent domination in the complementary prism  $G\overline{G}$ , obtained from the disjoint union of a graph  $G$  and its complement  $\overline{G}$  by joining corresponding vertices. We establish tight bounds

$$\max \{ \gamma_{ri2}(G), \gamma_{ri2}(\overline{G}) \} + 1 \leq \gamma_{ri2}(G\overline{G}) \leq n + 2,$$

and characterize the graphs attaining either bound.

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This is a joint work with Dragana Božović, and Aleksandra Tepeh.



## On the number of (shortest) subpaths in graphs

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The *subpath number*  $\text{pn}(G)$  of a graph  $G$  is the number of all subpaths of  $G$ , including those of length zero. Among connected graphs on  $n$  vertices, we show that  $\text{pn}(G)$  is minimized by any tree and maximized by the complete graph, while among bipartite graphs it is maximized by the complete bipartite graph with partite sets of almost equal size. We also give the exact formula for  $\text{pn}(G)$  for unicyclic graphs and cycle chains. Restricting the attention to geodesics, i.e. shortest paths connecting a pair of vertices of  $G$ , we define the *geodesic subpath number*  $\text{gpn}(G)$  as the number of geodesics in  $G$ . It is minimized precisely by geodetic graphs, defined as graphs in which every pair of vertices is connected by a unique geodesic. For the maximum we establish an upper bound on  $\text{gpn}(G)$  in terms of  $n$  and consider several graph families for which the value of  $\text{gpn}(G)$  can be expected to be large, yet the bound is not attained by any of them. Finally, for cactus graphs on  $n$  vertices with  $k$  cycles we characterize the extremal graphs with respect to  $\text{gpn}(G)$ .

This is a joint work with Martin Knor, Riste Škrekovski, Yu Yang and Xiao-Dong Zhang.



## Generalization of Renyi's car parking problem

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In this talk we study a variant of the famous Rényi's car parking problem in which we are parking isosceles triangles on a strip of height 1, and where the base of the triangle can be on either side of that strip. We find the exact value of the parking constant for this model, and we comment on some generalizations.



## On some switching of designs and graphs

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Switching methods can be seen as certain local transformations that do not alter the basic parameters of a combinatorial structure. The combinatorial structures we consider in this talk are graphs and designs. We show an extension of the known switching method for constructing 2-designs to divisible designs. Moreover, we show equivalences between switching methods for graphs and designs.

This is a joint work with A. Abiad, D. Crnković and L. Peters.



# On intrinsic formulas for Euclidean and hyperbolic Atiyah determinants

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In 2001 Sir M. F. Atiyah formulated a conjecture  $C1$  and later with P. Sutcliffe two stronger conjectures  $C2$  and  $C3$ . These conjectures, inspired by physics (spin-statistics theorem of quantum mechanics), are geometrically defined for any configuration of  $n$  points in the Euclidean three space (and hyperbolic space). The conjecture  $C1$  is proved for  $n = 3$  in [1] and for  $n = 4$  in [2], and  $C1$ ,  $C2$ , and  $C3$  in [3]. For  $n=5$   $C1$  for arbitrary five points in the Euclidean plane our computer symbolic certificate produces a new remarkable universal ('one hundred pages long') positive polynomial invariant, in terms of newly discovered shear coordinates. This refines the original Atiyah's conjecture and we are optimistic for its verification for  $n$  greater than five, (Atiyah was less optimistic ... 'It remains a conjecture for 300 years (like Fermat)' (see Atiyah: Edinburgh Lectures 2010). In the year 2013 Atiyah's conjectures were put on the new list of Nine open problems (from [4]) (which are 'probably' easier than the remaining six of famous Seven Clay millennium problems). In [3], for each graph  $G$  on given  $n$  points we defined generalized Atiyah's energies whose sum is  $n!$ . Further a new (weighted) extensions of the Atiyah Sutcliffe conjectures are formulated in [5].

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## Cubes of symmetric designs and group actions

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A 3-dimensional cube of a symmetric  $(v, k, \lambda)$  design is a map from  $[v]^3$  to  $\{0, 1\}$  such that every slice of a cube is an incidence matrix of a  $(v, k, \lambda)$  symmetric design. We introduce a regular action of a group  $G$  of order  $v$  on slices of a cube and generalize classical results about regular action of a group on a symmetric design to a case of dimension 3. Additionally, we prove that a group action on one set of parallel slices fully determines an action of  $G$  on other perpendicular slices. We also prove that it is not possible to have two sides with a common first coordinate as left (or right)  $G$ -orbits simultaneously. Furthermore, we prove that possible  $G$  orbits of mutually perpendicular slices alternate in a sense of being a left and right  $G$ -orbit. These results are extended on difference cubes as well.



## Geodesic-based Structures in Cube-like Graphs

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Cube-like graphs constitute an important class of combinatorial structures with applications in discrete mathematics, graph theory, computer science, and interconnection network theory. Among these structures, Fibonacci cubes and Lucas cubes have attracted considerable attention due to their rich combinatorial, structural, and metric properties.

In this talk, we focus on Fibonacci-like cubes and investigate their structural and metric properties. In particular, we study mutual visibility and edge general position sets, two graph-theoretic concepts defined in terms of shortest paths.



## On $k$ -limited domination in graphs

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In this talk, we present a new type of domination in graphs, called  *$k$ -limited domination*. The concept is motivated by applications in which dominating vertices have limited capacity and cannot serve too many vertices outside the dominating set. More precisely, for an integer  $k \geq 1$ , a dominating set  $D \subseteq V(G)$  is said to be  $k$ -limited if every vertex of  $D$  has at most  $k$  neighbors outside  $D$ . The minimum size of such a set is denoted by  $\gamma_k^L(G)$ . While the case  $k \geq \Delta(G)$  reduces to classical domination, the range  $1 \leq k < \Delta(G)$  imposes an additional capacity constraint and therefore leads to a substantially different domination problem. The talk will survey the known results from [1, 2]. \* This work has been supported by the European Commis-

sion's Horizon Europe Research and Innovation programme through the Marie Skłodowska-Curie Actions Staff Exchanges (MSCA-SE) under Grant Agreement no.101182819 (COVER: (C)ombinatorial (O)ptimization for (V)ersatile Applications to (E)merging u(R)ban Problems)

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This is a joint work with Dragana Božović, Gordana Radić, and Žana Kovijanić-Vukićević.



## Relations Between Polynomials Based on Perfect Matchings and Independent Sets

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In this talk, we focus on catacondensed even ring systems (shortly CERS) without any linearly connected adjacent triple of finite faces. For such a graph  $G$ , we describe a bijection between the set of all perfect matchings (Kekulé structures) of  $G$  and the set of all independent sets of the inner dual of  $G$ , which enables us to prove the equality between three polynomials: the sextet polynomial of  $G$ , the independence polynomial of the inner dual of  $G$ , and the newly introduced link polynomial of  $G$ . These equalities imply that the number of perfect matchings of  $G$  equals the number of resonant sets of  $G$  and also the number of independent sets of the inner dual of  $G$ . Moreover, we show that the number of edges of the resonance graph of  $G$  coincides with the derivative of the mentioned polynomials evaluated at  $x = 1$ . Finally, we provide a generalization of these results to all peripherally 2-colorable graphs.

This is a joint work with Petra Žigert Pleteršek.



## Kirchhoff–Soltés problem in dense graphs

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The Kirchhoff Index of a connected graph is the sum of resistance distances between all pairs of vertices of the graph. A vertex of a graph is said to be good if its removal does not change the graph's Kirchhoff index. As the pursuit of finding a graph with every single vertex being a good vertex has proven quite challenging, this paper studies a relaxed version of the Soltés problem in the dense family of complete multipartite graph  $G$  of order  $n$  consisting of  $n-a-2b$  partites of cardinality 1 (we refer to these as singletons with  $s$  being the number of singletons) and the remaining partites with cardinality  $> 1$  satisfying the equations,

$$a = \frac{b^2 + 3b - 2}{4}, n = \frac{b(b+3)}{2}, s = \frac{b^2 - 5b + 2}{4}, \text{ where } b \geq 6, b \equiv 2, 3 \pmod{4}.$$

This paper proves the existence of an infinite family of graphs that act as solutions to the relaxed Kirchhoff–Soltés problem with the singletons as the good vertices.

This is a joint work with Adhithya Ravi and Tabitha Agnes Mangam.



## Robustness of Maximum Weighted Matchings under Edge Weight Perturbations: Theory, Sensitivity, and Numerical Experiments

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This paper studies the robustness of a unique maximum-weight perfect matching in a balanced bipartite assignment problem under bounded perturbations of edge weights. We first derive a simple gap-based sufficient condition for preserving unique optimality. We then specialize the classical stability radius under the Chebyshev norm to the assignment setting and express the exact worst-case threshold through the symmetric difference between the optimal perfect matching and its competitors. A direct matching-theoretic proof identifies an extremal perturbation attaining the threshold and shows how the gap-based guarantee follows from the exact radius. Structured examples and numerical experiments illustrate the distinction between worst-case robustness and empirical stability under random perturbations.

This is a joint work with Ivana Zubac.



## From orbits to new directed strongly regular graphs

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A regular directed graph  $\Gamma$  of degree  $k$  on  $n$  vertices is a directed strongly regular graph,  $DSRG(n, k, t, \lambda, \mu)$ , if the number of directed paths of length two from a vertex  $v$  to a vertex  $w$  is  $\lambda$  when there is an arc  $v \rightarrow w$ ,  $t$  when  $v = w$ , and  $\mu$  otherwise. Directed strongly regular graphs were introduced by Art Duval in 1988. A 1-design can be constructed by defining a basic block as a union of  $G_\alpha$ -orbits of a transitive permutation group. Using this construction, we obtain several new pairwise non-isomorphic directed strongly regular graphs with parameter sets that, to the best of our knowledge, were previously unknown.

This is a joint work with V. Mikulić Crnković.



## Vector-based graph similarity measures and root-indices

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In this talk, we introduce a novel class of distance/similarity measures which are based on multiple topological indices. In many cases, they can be computed in polynomial time, which makes our method computationally efficient in practice. We explore its applicability in two domains: analyzing random graph models in network theory and assessing molecular similarity among isomers in chemoinformatics.

Further, we introduce the root-indices as additional graph descriptors. These indices offer complementary structural information and enrich the characterization of graphs. Their inclusion enables a more detailed comparison of graph structures and can improve the discrimination between non-isomorphic graphs with similar properties. The presentation outlines the main concepts behind this approach.

This is a joint work with Simon Brezovnik, Matthias Dehmer, Izudin Redžepović, and Niko Tratnik.



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