Book of Abstracts

COMBINATORICS 2026

Naples, Italy
25–29 May 2026

This online version has been last updated on 21st May 2026. We invite all the participants to check that their data are correct and up to date.

The organizing committee thanks Luca Giuzzi
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Overview

Overview

Combinatorics 2026

The Combinatorics 2026 conference is organized through the joint effort of the combinatorics research groups based in Italy, with the local organization of the University of Naples Federico II. It will take place at the "Partenope Conference Center" in Naples, Italy, from 25 till 29 May 2026. This is the 23rd edition in the series of the Combinatorics conferences, held in Italy ever since 1981. The first meeting was held in 1981, and a new edition has been organized every two years ever since 1982, with the unfortunate exception of 2020, which was cancelled due to the Covid-19 pandemic. The main topics of the conference include, but are not limited to: *Algebraic Combinatorics, Algebraic Curves over Finite Fields, Coding Theory, Cryptography, Design Theory, Galois Geometries, Graph Theory, Incidence Structures, Matroid Theory, q-Analogues in Combinatorics.*

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- Alain Couvreur
  Inria Saclay, France
- Tao Feng
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- Sam Mattheus
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- Gretchen L. Matthews
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Overview

ICA Awards

During Combinatorics 2026, the two 2024 Hall Medals, one 2025 Hall Medal, and the 2025 Euler Medal of the ICA will be presented.

Hall Medals recognize extensive quality research with substantial international impact by Fellows or Associate Fellows of the ICA in mid-career.

Euler Medals recognize distinguished lifetime career contributions to combinatorial research by Fellows of the ICA, including those who remain active in research.

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- the *Institute of Combinatorics and its Applications (ICA)*;
- *The Combinatorics Consortium (TCC)*;
- the project *AspecT3G*, FRA 2024, University of Naples Federico II;
- the *Journal of Combinatorial Theory, Series A*.

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Invited talks

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The chromatic number of finite projective spaces

Anurag Bishnoi
Delft University of Technology (Netherlands)
Joint work with: Wouter Cames van Batenburg and Ananthakrishnan Ravi

Abstract

The chromatic number of a finite projective space is the minimum number of colors needed to color its points so that there are no monochromatic lines. I will present recent joint work in which we establish relations between the chromatic number of finite projective spaces and some problems from Ramsey theory. We prove new upper bounds on the chromatic number, which then imply new lower bounds on multicolor vector space Ramsey numbers. For the binary case, we also prove lower bounds using a connection with the classical multicolor Ramsey numbers of triangles. This connection suggests a new approach to making progress on one of the oldest open problems in Ramsey theory.

Keywords: Chromatic number; finite projective spaces; Ramsey theory; vector space Ramsey numbers; multicolor Ramsey numbers

MSC(2020): 05C15, 05D10, 51E20

References

[1] Anurag Bishnoi, Wouter Cames van Batenburg, and Ananthakrishnan Ravi. "*The chromatic number of finite projective spaces*", (arxiv:2512.01760 [math.CO]), 2025.

Freiman's $3k-4$ theorem for function fields

Alain Couvreur

Inria & École Polytechnique (France)

Joint work with: Gilles Zémor, University of Bordeaux, France

Abstract

A central object of study in additive combinatorics are "sumsets", *i.e.* Minkowski sums

$$A + B \stackrel{\text{def}}{=} \{a + b \ : \ a \in A, \ b \in B\}$$

where A, B are two finite subsets of an abelian group. In this area, many questions relate to so–called *inverse problems*, which consist in characterising pairs A, B whose cardinality is "small" compared to those of A, B. For instance, Freiman's famous "$3k-4$ Theorem" states that if $A + A$ has cardinality at most $3|A| - 4$, then A must be contained in a short arithmetic progression.

In the last decades, there has been a growing interest for "linear analogues" of additive theory. Given finite dimensional vector spaces S, T inside an algebra $\mathcal{A}$ over a field K, the analogue of the Minkowski sum, becomes the product of spaces:

$$ST \stackrel{\text{def}}{=} \text{Span}_K\{st \ : \ s \in S, \ t \in T\}.$$

The study of such objects had various independent motivations arising from coding theory, cryptography or representation theory and permitted to establish unexpected links between additive combinatorics and algebraic geometry.

In this talk, we prove a function field analogue of Freiman's theorem that is also a generalisation: it states that if S is a finite dimensional K–vector space inside an extension F/K in which K is algebraically closed, and if S^2 has dimension at most $3(\dim S) - 4$, then S is contained in a Riemann-Roch space of a function field of small genus.

This is a **common work with Gilles Zémor** (University of Bordeaux).

Keywords: additive combinatorics, inverse problems, function fields, Riemann Roch spaces

MSC(2020): 11P70, 11R58, 14H05

MSC(2020): 05B15, 05B20, 05A05

Complete mappings, orthogonal orthomorphisms of groups and difference matrices

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Abstract

A complete mapping of a finite group G is a permutation $\phi : G \to G$ such that $x \mapsto x\phi(x)$ is also a permutation. A permutation $\theta : G \to G$ is an orthomorphism of G if the mapping $x \mapsto x^{-1}\theta(x)$ is also a permutation. Two orthomorphisms θ and ϕ of G are orthogonal if the mapping $x \mapsto \theta(x)^{-1}\phi(x)$ is bijective. This talk provides a brief introduction to the existence of complete mappings and orthogonal orthomorphisms of groups, focusing on their algebraic and extremal aspects. Difference matrices have a close relationship with orthogonal orthomorphisms of groups. This talk will also give a survey on difference matrices and their related topics, such as orthogonal arrays and mutually orthogonal Latin squares.

Keywords: complete mapping; orthomorphism; difference matrix; Hall–Paige conjecture

References

[1] Shikang Yu, Tao Feng, Hengrui Liu. "*Complete mappings stabilizing a subgroup and their parities*", J. Comb. Theory Ser. A, **221**:106143, 2026.

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[3] Rong Pan, R. Julian R. Abel, Yudhistira A. Bunjamin, Tao Feng, Tiana J. Tsang Ung, Xiaomiao Wang, "*Difference matrices with five rows over finite abelian groups*", Des. Codes Crypt., **90**:367–386, 2022.

Explicit constructions in Ramsey theory

Sam Mattheus

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Abstract

For over 70 years, the probabilistic method has been the dominant approach in Ramsey theory. However, recent advances have demonstrated the power of explicit constructions, often rooted in finite geometry, to outperform traditional random models.

We will survey several of these results, highlighting the central role of finite geometry and outlining some open problems in the field.

Keywords: Ramsey theory; pseudorandomness; H-free graphs

MSC(2020): 05C55, 05D10

Multipoint Codes, Semigroups, and Applications

Gretchen L. Matthews

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Abstract

In this talk, we consider codes defined from curves over finite fields, with particular emphasis on constructions arising from divisors supported at multiple points. We consider associated Weierstrass semigroups and applications. While the classical example on the projective line with a divisor concentrated at the point at infinity yields Reed–Solomon codes as a one-point case, we focus on the broader and richer setting of multipoint codes. We examine families arising from higher-genus curves such as Hermitian curves, norm-trace curves, and curves from Kummer extensions, where explicit bases of Riemann–Roch spaces are available for divisors supported on collections of rational points, naturally leading to concrete and flexible multipoint constructions. These multipoint codes provide additional degrees of freedom that can be exploited to optimize parameters and structure; in particular, we present constructions of non-special divisors of small degree—necessarily multipoint—that give rise to linearly complementary dual (LCD) codes. We also discuss automorphisms of curves and their relationship to code automorphisms, highlighting how these symmetries extend to and enrich the multipoint setting, and we describe recent results showing how such automorphisms enable permutation decoding of burst errors, especially for Hermitian codes, with perspectives toward further applications of multipoint algebraic geometry codes as time permits.

Keywords: Algebraic geometry codes; multipoint codes; Weierstrass semigroups; Riemann–Roch spaces; permutation decoding.

MSC(2020): 94B27, 11G20, 14H55, 11T71

Algebraic and geometric methods in DNA storage systems

Maria Montanucci

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Joint work with: Peter Beelen, Roni Con, Anina Gruica, Eitan Yaakobi, Ferdinando Zullo

Abstract

As the amount of data produced globally continues to rise exponentially, the demand for efficient, durable, and scalable storage solutions has become critical [11]. Traditional storage technologies struggle to keep up with this growth, both in terms of physical space and energy efficiency. DNA storage has emerged as a promising alternative [1, 5, 6, 10, 14, 13, 2], attracting significant attention due to its potential for extreme data density and long-term stability [11, 12]. This alternative approach to data storage has attracted growing interest across fields such as biology, chemistry, computer science, electrical engineering and also mathematics. However, despite its promise, DNA storage still faces significant challenges and presents many open questions [7, 12, 15], some of which will be the foundation of this talk.

The DNA storage process generally involves three main steps: DNA synthesis, DNA storage, and DNA sequencing. Digital data, typically represented as a string of bits, is first encoded into sequences over the DNA alphabet $\{A, C, G, T\}$. This encoded string is divided into blocks, and then synthesized into actual DNA strands. These strands are stored in a container, where each strand exists in numerous copies, but in a completely unordered manner.

When a user wants to access the stored data, sequencing technology retrieves a multiset of "reads"– copies of the strands that may contain errors. By obtaining enough reads, users can reconstruct the original data. The number of reads required for accurate data retrieval is called *coverage depth*, and reducing this depth is crucial for lowering sequencing costs and improving retrieval speed [9].

To reduce the cost of DNA synthesis and sequencing, which is one of the main drawbacks of using synthesized DNA as a storage solution, error-correcting codes have been used to make the process more efficient, through reducing the number of strands needed for data retrieval.

In this talk, we will discuss two important aspects related to DNA storage, namely Random-access problem and insertion-deletion error correction. More precisely the talk will be divided into the following two parts.

MSC(2020): 94B25, 94B60, 68P20, 94B27

- In the first part, we focus on a specific problem arising in DNA storage systems known as the **Random Access Problem**, initially introduced in [3]. This problem concerns the scenario in which a user wants to retrieve only one specific information strand from a storage system. Assuming error-free synthesis and sequencing, we aim to study and determine error-correcting codes that reduce the expected number of reads necessary to access this target strand. To achieve this, it is crucial to understand which properties of error-correcting codes play a role in reducing the expected number of reads required for reliable data retrieval. In our approach [8], we look at this problem from a geometric perspective, which provides new insights into what properties of codes play a role for them to perform well in terms of the random access problem in DNA storage systems. Moreover, studying this problem from this viewpoint allows to derive clean formulas for computing the random access expectation, for certain classes of codes. In contrast, previous work often involved formulas that were challenging to handle or analyze explicitly.
- In the second and final part of this talk, we describe the most common errors occurring when dealing with DNA storage systems, namely **insertion-deletion errors**. Using classical error-correcting codes to deal with this type of errors is natural, but their actual performance is still not fully understood. In fact, the performance of Reed–Solomon (RS) codes in this scenario has attracted growing attention in recent literature. In our work [4], we further study this intriguing mathematical problem, focusing on two regimes. First, we study the question of how well full length RS codes perform against insertions and deletions. For 2-dimensional RS codes, we provide a complete characterization of codes that cannot correct even a single insertion or deletion. Furthermore, we prove that for sufficiently large field size q, nearly all full-length 2-dimensional RS codes can correct up to $(1-\delta)q$ insertion and deletion errors for any $0<\delta<1$. Extending beyond the 2-dimensional case, we show that for any $k \geq 2$, there exists a full-length k-dimensional RS code capable of correcting $q/(10k)$ insertion and deletion errors, provided q is large enough. Second, we focus on rate-$1/2$ RS codes that can correct a single insertion or deletion error. We present a polynomial-time algorithm that constructs such codes over fields of size $q = O(k^4)$.

Keywords: DNA storage, Random access problem, insertion-deletion errors.

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Some recent results on $\mathbb{F}_q$-linear sets of $\mathrm{PG}(r-1, q^n)$

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Abstract

An $\mathbb{F}_q$-linear sets of rank $m \geq r$ can be seen either as

- the set of points of $\mathrm{PG}(r-1, q^n)$ defined by an $\mathbb{F}_q$-vector space of dimension m or
- the projection of a subgeometry of order q of $\mathrm{PG}(m-1, q^n)$ on a $\mathrm{PG}(r-1, q^n)$ or
- the elements of a Desarguesian spread of $\mathrm{PG}(rn-1, q)$ with non empty intersection with a $\mathrm{PG}(m-1, q)$.

We will present a unifying approach that comprises the three different definitions, in light of which we have been able to prove some structural results about linear sets.

MSC(2020): 51E20, 05B25

Geometric approach to the Berge conjecture

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MSC(2020): 05C70, 05C21, 05B25

Abstract

A fascinating conjecture of Berge suggests that every bridgeless cubic graph can have its edges covered with at most five perfect matchings. Since three perfect matchings suffice only when the graph is 3-edge-colourable, the remaining cubic graphs (*snarks*) fall into two classes: those that can be covered with four perfect matchings, and those that need at least five. Several profound and longstanding conjectures in graph theory – such as the 5-cycle-double cover conjecture, the short cycle cover conjecture of Alon and Tarsi, or the Fan-Raspaud conjecture – are known to be true for graphs that admit a cover with four perfect matchings. Therefore, understanding the cubic graphs that require more than four perfect matchings to cover their edges is fundamental for the progress that might lead to proving or disproving any of these conjectures.

A significant obstacle is the fact that examples of cubic graphs that cannot be covered with four perfect matchings are extremely rare and difficult to find. In this talk we outline a theory that describes coverings with four perfect matchings as flows whose values are points and outflow patterns are lines of a tetrahedron spanned by four points of the 3-dimensional projective space $\mathbb{P}_3(\mathbb{F}_2)$ over the 2-element field in general position. This theory provides a powerful tool for investigating the graphs that do not admit such a cover and leads to a number of new results. Among them are, for instance, (i) unification all previously known examples and constructions into a single family [1], (ii) disproving conjectures that attribute certain properties to cubic graphs that cannot be covered with four perfect matchings [2, 3], (iii) the proof of NP-completeness of the problem to decide whether a snark can be covered with four perfect matchings [2], and (iv) a great variety of constructions of snarks that cannot be covered with four perfect matchings [1, 2, 3, 2, 5].

This talk is based on several published papers, and some forthcoming ones, co-authored by Edita Máčajová and Peter Varša.

Keywords: cubic graph; perfect matching; nowhere-zero flow, projective space.

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MSC(2020): 05C70, 05C21, 05B25

MSC(2020): 05B07, 05B10, 20B25, 94A62

Spot the *differences*: classic and external families

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Abstract

Difference families (DFs) have been extensively studied [1] due to their important applications and their role in the construction of various objects: from combinatorial designs having a nearly sharply-transitive automorphism group to optical orthogonal codes. Recently, external DFs have been introduced [4] as a powerful tool for constructing algebraic manipulation detection codes.

In this talk, after discussing the connections between the two types of DFs and some applications, we will focus on recent existence results. In particular, we will present a special type of classic DFs which play a central role in the construction of Steiner and Kirkman triple systems admitting an automorphism group that fixes f points and acts sharply transitively on the remaining ones [3]. Finally, we will discuss some recent developments on circular external difference families [2].

Keywords: Difference family, automorphism group, triple system, AMD code

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On the autotopism groups and the equivalence of finite cyclic semifields

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Joint work with: Paolo Santonastaso

Abstract

Special cases of finite cyclic semifields were first constructed by Hughes and Kleinfeld in 1960, and later by Sandler in 1962 and Knuth in 1965. The general construction of cyclic semifields was subsequently introduced by Petit in 1966, and later rediscovered from the perspective of irreducible semilinear transformations by Jha and Johnson in 1989. Since Sandler's foundational work in 1962, the complete determination of the autotopism groups of cyclic semifields and the full resolution of the isotopy problem for this family have remained long-standing open problems. The most significant advances in determining these autotopism groups are due to Dempwolff in 2011, who left open the case in which the field extension degree strictly divides the degree of the polynomial defining the semifield.

In this talk, we provide a complete classification of cyclic semifields up to isotopy, together with the full determination of their autotopism groups, thereby closing the remaining cases left open by Dempwolff. Since cyclic semifields arise as a special instance of a broader family of maximum rank distance (MRD) codes constructed via skew polynomials, our methods also yield a complete classification of these MRD codes up to linear and semilinear equivalence over the prime field, together with an explicit description of their full automorphism groups.

Keywords: Cyclic semifield; autotopism group; rank-metric code; semilinear transformation; skew polynomial

MSC(2020): 12K10; 11T71; 16S36; 15A04

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Some families of linear codes containing non-GRS MDS codes

Kanat Abdukhalikov

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Joint work with: C. Ding and G. K. Verma

Abstract

We investigate several classes of MDS codes and provide necessary and sufficient conditions for these codes to be non-GRS MDS codes. We also determine their parity-check matrices. Furthermore, we characterize their self-orthogonality and self-duality properties and present explicit constructions and examples. In addition, by exploiting the connection between MDS codes and arcs in finite projective spaces, we obtain a new characterization of o-monomials [1, 2].

Keywords: MDS codes, GRS codes, non-GRS MDS codes, parity check matrices, self-orthogonal codes, n-arcs, o-polynomials, hyperovals

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MSC(2020): 94B05, 94B65, 05B25, 51E21

Additive quasi-conjucyclic codes

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Joint work with: Arezoo Soufi Karbaski, Irfan Siap

Abstract

Let R be a commutative ring of order p^2, where p is any prime integer. An additive code of length an integer n over the ring R is a subgroup of R^n. For any $a \in C$, we let $\overline{a}$ denotes the conjugate of a. If $n = ml$, any element in R^n will be represented as $c = (\overrightarrow{c_0}, \overrightarrow{c_1}, ..., \overrightarrow{c_{m-1}})$, where $\overrightarrow{c_j} = (c_{j,0}, c_{j,1}, ..., c_{j,l-1})$ for all $j = 0, 1, ..., m-1$.

Definition 1. An additive code of length $n = ml$ over R is called a quasi-conjucyclic code of length n and index l if $(\overrightarrow{c_0}, \overrightarrow{c_1}, ..., \overrightarrow{c_{m-1}}) \in C$ implies that $(\overrightarrow{c_{m-1}}, \overrightarrow{c_0}, \overrightarrow{c_1}, ..., \overrightarrow{c_{m-2}}) \in C$.

In this paper, we are interested in studying the algebraic structure of additive quasi-conjucyclic codes of length $n = ml$ over the ring R. Our approach will be based on realizing that the ring R of order p^2 is isomorphic to the ring $\mathbb{Z}[i]/ < p >$, where $\mathbb{Z}[i] = \{a + bi : a, b \in \mathbb{Z}$ and $i^2 = -1\}$ is the Gaussian integers ring [1]. The following Theorem will give the algebraic structure of these codes

Theorem 2. *Let C be any quasi-conjucyclic code of length $n = ml$ over R. Then $C = C_1 \oplus iC_2$, where C_1 and C_2 are linear quasi-cyclic and quasi-twisted codes of length $n = ml$ and index l over the finite field $\mathbb{Z}_p$, respectively.*

MSC(2020): 94B05, 94B15

Keywords: Quasi-cyclic codes; quasi-twisted codes.

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Even Sets and Dual Projective Geometric Codes: A Tale of Cylinders

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Abstract

An *even set* is a non-empty set of points in $\mathrm{PG}(n,q)$, with q even, that intersects every line in an even number of points. It follows from a quite involved coding-theoretic proof that the smallest even sets in $\mathrm{PG}(n,q)$ have size $q^{n-2}(q+2)$. In this talk, we discuss a very short combinatorial proof of this bound, and characterise even sets meeting this bound.

Theorem 1 ([2]). *Let S be an even set in* $\mathrm{PG}(n,q)$. *Then $|S| \geq q^{n-2}(q+2)$ with equality if and only if S is a* cylinder *with a hyperoval as base.*

This fits into the broader theory of *dual projective geometric codes*. Let p be any prime, and q a power of p. Let $\mathcal{C}_1(n,q)^\perp$ denote the vector space of functions c from the points of $\mathrm{PG}(n,q)$ to $\mathbb{F}_p$ such that for each line ℓ, $\sum_{P\in\ell} c(P) = 0$. Denote the minimum distance of this code as $d(\mathcal{C}_1(n,q)^\perp)$.

Theorem 2 ([2]). *If $n > 2$, then $d(\mathcal{C}_1(n,q)^\perp) = q^{n-2} d(\mathcal{C}_1(2,q)^\perp)$.*

We conjecture that the minimum weight codewords of $\mathcal{C}_1(n,q)^\perp$ have a cylindrical structure. This is known to hold if q is prime, and Theorem 1 proves it if q is even.

Keywords: Finite geometry; Projective; Even sets; Projective Geometric Codes.

MSC(2020): 51E20, 94B52, 05B25.

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On the (expanded) Buratti-Horak-Rosa Conjecture for Small Supports

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Joint work with: M. A. Ollis, Emerson College, USA

Abstract

Label the vertices of the complete graph K_v with the distinct elements of $\mathbb{Z}_v$ and define the *length* ℓ of each edge as the cyclical distance between the labels of its end-vertices. A Hamiltonian path through K_v is called a *realization* of a given multiset L if its edge labels are L. The *Buratti-Horak-Rosa Conjecture* is that there is a realization for a multiset L if and only if for any divisor d of v the number of multiples of d in L is at most $v - d$.

The toroidal lattices of vertices associated with circulant graphs are useful for constructing special types of realizations, the concatenations of which yield realizations for larger multisets [1, 2]. We will present how this approach has been considerably extending the parameters for which the conjecture is known to hold (using as an example the case of multisets with support of the form $\{1, x, y\}$ for relatively small lower bounds on the number of 1-edges), and how it can be modified for certain instances of Buratti's expanded conjecture(s) (announced in Combinatorics 2014) concerning cycle decompositions.

Keywords: complete graph, Hamiltonian path, edge-length, realization, toroidal lattice, cycle decomposition

MSC(2020): 05C38, 05C78

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MSC(2020): 51E20, 05B25

Barlotti–Cofman Representation of quasi-Hermitian varieties

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Joint work with: Viola Siconolfi

Abstract

Quasi-Hermitian varieties in $PG(n, q^2)$ are point sets having the same intersection numbers with hyperplanes as a non-singular Hermitian variety, and include the non-classical Buekenhout–Metz (BM) and Buekenhout–Tits (BT) families (see [1, 2]). Their combinatorial structure is closely related to two-weight codes and strongly regular graphs.

In this talk we explicitly determine the Barlotti–Cofman (BC) representation of BM and BT quasi-Hermitian varieties in $PG(3, q^2)$, embedded in $PG(6, q)$. We prove that BM quasi-Hermitian varieties correspond to quadratic cones with hyperbolic base, while in the BT case the associated non-quadratic hypersurfaces admit a cone-like description. Although a similar description holds for classical Hermitian varieties (see [2]), the distinction lies in the configuration of the section at infinity, whose structure we determine in terms of spread elements.

These results provide a geometric interpretation of the non-classical nature of BM and BT varieties within the BC representation.

Keywords: unital; Hermitian and quasi-Hermitian variety; spread

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Cayley graphs, flows and pseudoforests

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Joint work with: István Kovács

Abstract

In this talk, we discuss the existence of nowhere-zero flows in graphs, with a particular focus on Cayley graphs. We begin by introducing the basic concepts and motivations behind flows, and then consider their behavior in Cayley graphs, a class of graphs with a high degree of symmetry.

We review Tutte's classical conjectures on nowhere-zero flows and discuss their relevance in the setting of Cayley graphs. We then examine connections between flows and pseudoforests in graphs, showing how these relationships lead to new insight into the existence and construction of flows. We conclude by presenting the following result.

Theorem 1. *Let G be a solvable group of order $2n$, where n is square-free. Then every connected Cayley graph of valency at least 4 on G admits a nowhere-zero 3-flow.*

Keywords: nowhere-zero 3-flow; pseudoforest; Cayley graph.

References

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MSC(2020): 05C21, 05C25.

Length-Maximal Codes, Existence and Structure

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Abstract

An $(n, q^k, d)_q$ A^{s}MDS code C is a code of singleton defect $s = n - k + 1 - d$. Such a code satisfies $n \leq (s+1)(q+1) + k - 2$, and in the case of equality, C is said to be *length-maximal*.

The length-maximal $[n, k, d]_q$ linear codes thus correspond to maximal arcs in $PG(k-1, q)$. We will discuss existence questions surrounding length-maximal codes, including a generalization of a result of Barlotti, whereby linear codes of dimension $k \geq 3$ admit unique extensions to length-maximal codes.

Linear A^{s}MDS codes of sufficient length are necessarily projective and dual to AMDS codes, such properties may be exploited to develop arithmetic conditions that restrict the existence of length-maximal codes.

Time permitting, we shall widen discussion to length-maximal non-linear codes.

Keywords: maximal arcs; singleton defect; linear codes; non-linear codes

MSC(2020): 00X01, 01X02

Minimal additive codes

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Joint work with: Marine Le Meur

Abstract

An *additive code* of length n over the finite field $\mathbb{F}_{q^h}$ is a subset $\mathcal{C}$ of $\mathbb{F}_{q^h})^n$ that is closed under addition. Such a code is linear over the subfield $\mathbb{F}_q$ and therefore has size q^r for some r. For short, we denote $\mathcal{C}$ by $[n, r/h, d]_q^h$, where the parameter d is the minimum Hamming distance of $\mathcal{C}$. Additive codes are particularly interesting because, in certain cases, they outperform linear codes. However, still very few cases are known and the explicit construction of such codes is a challenging problem. Moreover, they play a central role in quantum error correction.

In this talk, we adopt the geometric perspective on additive codes introduced in [1] and further investigated in [2]. We introduce the notions of *minimal additive codes* and *additive strong blocking sets* in projective spaces. We establish a one-to-one correspondence between these two objects and investigate the resulting structural properties.

Keywords: Minimal codes; additive codes; strong blocking sets.

References

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MSC(2020): 94B65, 51E20, 94B05

MSC(2020): 14A99,51E99

Nets of conics in PG$(2, q)$, q even

Nour Alnajjarine
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Joint work with: Michel Lavrauw

Abstract

A *net of conics* is a 2-dimensional linear system of conics in PG$(2, q)$. The classification of such nets, initiated in the early twentieth century, remains open and exhibits intriguing connections with partially symmetric $3 \times 3 \times 3$-tensors and symmetric rank-distance codes. Linear systems of conics over finite fields shows fundamentally different behaviour in even and odd characteristic. In this talk we focus on even characteristic. We will explain the progress which was made in recent years, including the classification of nets with non-empty base from [1] and of nets with a double line from [2].

Keywords: Nets of Conics; Finite Fields; Rank-Distance Codes; Partially Symmetric Tensors

References

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Minimal Value Set Binomials

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Joint work with: João Paulo Guardieiro

Abstract

Let p be a prime number, q a power of p, and $\mathbb{F}_q$ the finite field with q elements. A simple argument involving the maximum number of roots of a polynomial $F \in \mathbb{F}_q[x]$ allows one to conclude that $\left\lfloor \frac{q-1}{\deg F} \right\rfloor + 1 \leq \#V_F \leq q$, where $V_F = \{F(\alpha) : \alpha \in \mathbb{F}_q\}$ is the **value set** of the polynomial F. In this work, we are interested in polynomials that attain the lower bound for the cardinality of their value set. These are the so-called **minimal value set polynomials** (MVSPs). In [1], Borges provides a connection between MVSPs over $\mathbb{F}_q$ and $\mathbb{F}_q$-Frobenius nonclassical curves, that is, curves for which the image of any smooth point under the $\mathbb{F}_q$-Frobenius morphism lies on its tangent line. More precisely, he showed that the components of a curve given by the plane equation $f(x) = g(y)$ are $\mathbb{F}_q$-Frobenius nonclassical if, and only if, f and g are MVSPs with the same value set. In order to classify some of these curves, we characterized all minimal value set binomials. Using this information and the connection established by Borges, we then classified all Frobenius nonclassical quadrinomial curves with separated variables (see [2]).

Keywords: Finite fields; Minimal value set polynomials; Frobenius nonclassical curves.

MSC(2020): 11T06, 14H45

References

[1] Borges, H. *Frobenius nonclassical components of curves with separated variables.* Journal of Number Theory 159 (2016), 402–425.

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MSC(2020): 05A18, 05A15, 05A16, 05A17

Sum of elements preceding records in set partitions

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Joint work with: Noor Kezil

Abstract

In this research, we aim to derive an explicit formula for the total number of elements preceding records over all set partitions of $[n]$ with exactly k blocks, as well as an asymptotic estimate for the total sum of elements preceding records in all set partitions of $[n]$, expressed in terms of Bell numbers. To achieve this, we analyze the generating function that enumerates set partitions of $[n]$ according to this statistic, which we denote by sume.

Definition 1. A *set partition* Π of $[n]$ of size k is a collection $\{B_1, B_2, \ldots, B_k\}$ of nonempty disjoint subsets of $[n]$, called *blocks*, whose union is equal to $[n]$. We assume that blocks are listed in increasing order of their minimal elements, that is, $minB_1 < minB_2 < \cdots < minB_k$.

Definition 2. We define $\text{sume}_\text{a}(\pi)$ to be the sum of all elements preceding a record a in π, and define $\text{sume}(\pi)$ as the total sum of all such $\text{sume}_\text{a}(\pi)$ over all records in π.

Our main result is the following.

Theorem 3. *The total number of the* sume *over all set partitions of* $[n]$ *with exactly* k *blocks is*

$$S_{n,k}\sum_{a=1}^{k}\frac{a(a-1)}{2}+\sum_{i=1}^{k-1}\left(\frac{(k-i)i(i+1)}{2}\sum_{j=1}^{n-k}S_{n-j,k}i^{j-1}\right).$$

Theorem 4. *The total number of the* sume *over all set partitions of* $[n]$ *is*

$$\frac{1}{3}B_{n+3}-\frac{1}{4}B_{n+2}-(\frac{1}{2}n+\frac{13}{12})B_{n+1}-(\frac{1}{12}+\frac{1}{2}n)B_n.$$

Keywords: Records, Sum of elements preceding records, Set partitions, Generating functions, Bell numbers and Asymptotic estimate.

A Characterization of Some Linearized Reed-Solomon Codes

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Joint work with: Martino Borello, Alain Couvreur, Flavio Salizzoni

Abstract

Linearized Reed–Solomon codes are optimal sum-rank metric codes that generalize both Reed–Solomon and Gabidulin codes. While these families admit well-understood algebraic and geometric characterizations (see [3, 1] and [4, 2], respectively), no general distinguisher is known for Linearized Reed–Solomon codes. In this talk, we study their geometric structure and relate them to a q-analogue of the rational normal curve. This perspective leads to a geometric characterization of Linearized Reed–Solomon codes and provides an effective distinguisher for certain classes of them.

Keywords: Sum-rank metric; Linearized Reed-Solomon codes; Distinguisher.

MSC(2020): 11T71, 51E20, 94B27

References

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MSC(2020): 05-08, 05A05, 65F15, 65F05

Accurate computations with the ballot table

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Joint work with: Jorge Delgado and Juan Manuel Peña

Abstract

Riordan arrays introduced in [3] play a key role in combinatorics, particularly in recurrence relations, lattice paths, and combinatorial identities. Defined by two power series $f(t) = \sum_{n=0}^{\infty} f_n t_n$ and $g(t) = \sum_{n=1}^{\infty} g_n t_n$, the array $R(f, g) = (r_{nk})_{n,k\geq 0}$ satisfies that the generating function for its k-th column is $f(t)[g(t)]^k$ for all $k \geq 0$, corresponding to an infinite lower triangular matrix.

We first consider the Riordan array given by the ballot table (cf. [1]). This matrix arises from counting the number of ways candidate A can stay strictly ahead of candidate B during a sequential vote tally. This talk presents algorithms for computing high relative accuracy (HRA) bidiagonal representations of finite truncations of the ballot table, and also of the Fibonacci matrix. These factorizations enable HRA solution to key linear algebra problems, including matrix inverses, singular values and associated linear systems. Finally, we will show some numerical experiments that validate the theoretical results.

Keywords: Riordan Arrays, Ballot Table, Total Positivity, High Relative Accuracy

References

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Automorphism of Kimura Hadamard Matrices

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Joint work with: Melissa Lee - Monash University

Abstract

We discuss the structure of the automorphism groups of Kimura Hadamard matrices (KHMs) constructed from dihedral groups. We begin by identifying several natural families of automorphisms and show that every KHM admits a subgroup of automorphisms isomorphic to $D_{2k} \times Q_8$, or $C_2 \times D_{2k} \times Q_8$ in the case of y-invariant matrices. We then describe how additional automorphisms may arise from the holomorph of the dihedral group when certain structural conditions are satisfied. Comparing these results with known examples, including those constructed by Kimura and Niwasaki, and matrices arising from the Shinoda–Yamada construction, we identify counterexamples to a conjecture of Ó Cathaín. The evidence suggests that, apart from the automorphisms predicted by this framework, no further automorphisms occur.

Keywords: Hadamard Matrices; Dihedral Groups; Kimura.

MSC(2020): 05B10, 05B20 and 20J06.

Generalized quadrangles of order s with regularity properties

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Joint work with: Bart De Bruyn and Koen Thas

Abstract

Let Q be a thick generalized quadrangle (GQ) of order s. If Q has a hyperbolic line consisting of centers of symmetry or regular points, then it is isomorphic to the symplectic generalized quadrangle $W(s)$ [1, 2, 3]. Our aim is to characterize symplectic GQs under weaker conditions. An ordered non-incident point-line pair (y, L) is called *juxtaregular in* y if (y, l) is regular for all lIL. Moreover, if x is a point of L, non-collinear to y, that is (a center of symmetry) regular, we call the triple (x, L, y) *(strongly) sesquiregular*.

I will discuss characterizations of symplectic GQs using some alternative notions of regularity. In particular the following result will be discussed.

Theorem 1. *Let Q be a generalized quadrangle of order s with a strongly sesquiregular triple. If $s \in \{7, 9\}$, then $Q \cong W(s)$. If $s = 8$, then either $Q \cong W(8)$ or $Q \cong T_2(O)$ for an oval O of* $\mathrm{PG}(2, 8)$.

Keywords: (Symplectic) Generalized Quadrangles; Latin Squares; Regular Points

MSC(2020): 51E12, 05B15, 51E15

References

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Embeddings, Enumeration, and Errors: Combinatorial Problems in Projective Metrics

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Joint work with: Gabor Riccardi, University of Pavia

Abstract

Projective metrics, also known as *projective point set metrics* or $\mathcal{F}$*-metrics*, were first introduced by Gabidulin and Simonis in 1997 as a large class of metrics generalizing well-known metrics in coding theory, like the *Hamming metric*, the *(sum)rank metric*, and *combinatorial metrics* such as *burst metrics*.

Definition 1. Given a spanning subset $\mathcal{F}$ of a finite vector space V over $\mathbb{F}_q$, the corresponding projective *weight* $wt_{\mathcal{F}}$ on V is given by

$$wt_{\mathcal{F}}(x) := \min\{|S| \ : \ S \subset \mathcal{F}, \, x \in Span_{\mathbb{F}_q}(S)\}.$$

Likewise, the corresponding projecive *metric* on V is $d_{\mathcal{F}}(x, y) := wt_{\mathcal{F}}(y - x)$.

Projective metrics have strong connections to the theory of coset leaders, supports, hyperplane arrangements, projective geometry, graph theory and representable matroids. Also, they allow embeddings of more general metric spaces:

Theorem 2 ([1]). *Any finite scale-translation-invariant metric space over* $\mathbb{F}_q$ *can be linearly embedded in a finite projective metric space over* $\mathbb{F}_q$.

This begs the question: a given finite scale-translation-invariant metric space, what is a smallest projective metric that it can be linearly embedded into? In this talk we will discuss this problem, as well as emumerative problems on bounds on codes in projective metrics and their weight distributions.

Keywords: Bounds on codes, metric spaces, projective geometry

MSC(2020): 14N10, 32F45, 51E20, 94B65

References

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Minimal Codewords of Codes from Directed Graphs

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Joint work with: Dr. Romar B. dela Cruz and Dr. Manuel Joseph C. Loquias

Abstract

Minimal codewords are nonzero codewords whose support do not cover the support of another nonzero codeword. In [1], Kurz identified the number of minimal codewords in binary linear codes generated by appending the adjacency matrix of certain undirected graphs to the identity matrix. We investigate the minimum and/or maximum number of minimal codewords from orientations of undirected graphs, focusing on path graphs, cycle graphs, complete graphs, and complete bipartite graphs.

Keywords: Minimal codewords; Directed graphs; Linear codes

MSC(2020): 94B05, 94B25, 05C20

References

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Polytope–Tableau Correspondences for Type A KR Crystals

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Joint work with: Irfan Habib

Abstract

In this talk we study the polytope model of the Kirillov–Reshetikhin (KR) crystal $KR^{i,m}$ for type A. We give an inductive formula for producing a path from the highest weight element to any given vertex in the crystal graph. For $i \leq 2$ or $i \geq n-1$, we determine the explicit image of any element under the affine crystal isomorphisms between the polytope and the tableau realizations of the KR crystals.

Definition 1. The set $B_n^{i,m}$ along with the usual crystal operators e_ℓ, f_ℓ and crystal functions $\epsilon_\ell, \varphi_\ell$ for $\ell \in \{i, i+1, \ldots, n\}$ gives the polytope model of KR crystal $KR^{i,m}$ for type A.

Our main result is the following.

Theorem 2. *For $A \in B_n^{i,m}$, the operator $\mathcal{K}^{A^{(r^A)}} \cdots \mathcal{K}^{A^{(n)}}$ sends the highest weight element to A, where*

$$\mathcal{K}^{A^{(k)}} = \Big(\prod_{j=i+1}^{k} f_{k+i+1-j}^{\varphi_{k+i+1-j}}\Big)\Big(\prod_{j=t^{A^{(k)}}+1}^{i} e_{i+t^{A^{(k)}}+1-j}^{h(k)}\Big)\Big(f_t^{g(k)} \prod_{j=t^{A^{(k)}}+1}^{i} f_j^{\varphi_j}\Big),$$

and $r^A, t^A, A^{(k)}, h(k), g(k)$ are appropriately defined for $r^A \leq k \leq n$.

Keywords: KR crystals, crystal graphs, polytope model, Young tableaux

MSC(2020): 05E10, 17B37, 05E05

References

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Tensor Rank of Matrix Codes from Products of AG Codes

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Joint work with: E. Byrne and G. Cotardo

Abstract

Connections between algebraic geometry and tensor methods continue to deepen our understanding of rank-metric and matrix codes. Foundational results already show that products of Cauchy codes attain optimal tensor-rank behaviour, as established in [1]. In this talk we extend this perspective by constructing rank-metric codes from products of algebraic geometry (AG) codes defined by triples of divisors on suitable curves. Our approach yields a geometric criterion ensuring that these AG-code products have trivial intersections, allowing precise control of the tensor representation of the associated matrix codes. When specialising to elliptic curves, we obtain explicit families of optimal rank-metric codes whose tensor-rank defect is equal to 1.

Keywords: Rank metric codes; AG codes; tensor rank; Elliptic codes

MSC(2020): 94B27, 11T71, 15A69

References

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The geometry of rank-metric codes

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Joint work with: G.N. Alfarano and A. Neri

Abstract

It is well known that linear codes in the Hamming metric can be interpreted geometrically as sets of projective points. More recently, additive codes in the Hamming metric [2] and vector rank-metric codes [3] have also been studied from a geometric perspective, corresponding respectively to sets of subspaces and to q-systems with their associated linear sets.

In this talk we introduce a geometric framework for matrix codes in the rank metric [1]. Starting from a generator tensor whose horizontal slices generate the code, we define the associated column- and row-systems through vertical slices in the two directions. This viewpoint allows one to reinterpret the metric via intersections with hyperplanes and to define notions such as subspace weights, evasiveness, generalized weights, and associated Hamming-metric codes, leading to applications in the study of weight distributions and constant-weight codes.

Keywords: Rank-metric codes; q-systems; generator tensor

MSC(2020): 94B27, 51E22

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Cliques in Graphs Constructed from Strongly Orthogonal Subsets in Exceptional Root Systems

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Joint work with: Pádraig Ó Catháin

Abstract

Given a root system R, two roots are said to be *strongly orthogonal* if neither their sum nor difference is a root. The graph $\Gamma(R, k)$ has vertices labelled by sums of k-element strongly orthogonal subsets of roots, and edges connect vertices whose difference is also a vertex. These graphs were defined by Gashi, who established Erdős–Ko–Rado type results for the graphs $\Gamma(A_\ell, k)$ in work with the current authors. In this talk, we study the graphs $\Gamma(R, k)$ for the exceptional root systems G_2, F_4, E_6, E_7, and E_8. We compute graph-theoretic invariants including regularity, connectivity, and clique numbers, and analyse clique structures with respect to sunflower properties. The automorphism group contains the Weyl group $W(R)$; we use these symmetries to obtain complete counts of maximum cliques and maximum sunflowers. Unlike type A, where all maximal cliques are sunflowers for large rank, sunflower cliques comprise at most 11% of maximum cliques in the simply-laced exceptional types E_6, E_7, and E_8.

Keywords: root systems, strongly orthogonal roots, Erdős–Ko–Rado theorem, clique number, sunflower.

MSC(2020): 05C69, 05D05, 17B22

A New Representation-Theoretic Approach to the Spectrum of Kneser-Type Graphs

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Joint work with: Nathan Lindzey

Abstract

We present a representation-theoretic approach to deriving the eigenvalues of Kneser-type graphs that emphasizes a simple and unifying framework. Our method views these graphs as disjointness graphs arising from bounded graded meet-semilattices and expresses their adjacency matrices in terms of natural incidence matrices.

For the Kneser graph $KG(n,k)$, this perspective yields sparse, highly structured eigenvectors from the action of the symmetric group, leading directly to the eigenvalues

$$\eta_j = (-1)^j \binom{n-k-j}{k-j}, \qquad j = 0, 1, \ldots, k.$$

We show that this approach extends naturally to the q-Kneser graph $KG_q(n,m)$, where analogous sparse eigenvectors from the representation theory of $GL_n(q)$ give the corresponding q-analogs of the eigenvalues.

This provides a transparent and unified algebraic framework for computing the spectra of Kneser-type graphs.

Keywords: Representation Theory, q-Kneser Graph, Spectrum

MSC(2020): 05D05, 05E10

Additive Steiner 2-designs

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Abstract

A 2-design is *additive* if, up to isomorphism, its points are elements of an abelian group G, and the sum of the points in each block is zero in G. This intriguing concept was introduced in [5] and paved the way to the more general notion of "additive combinatorial designs" [2] which include several older constructions of various types of combinatorial structures as, for instance, the *Heffter Spaces* [1].

In this talk, I will focus on additive Steiner 2-designs [1, 2, 3], the study of which is particularly challenging.

Keywords: (additive) Steiner 2-design, q-analog of a Steiner 2-design

MSC(2020): 05B05, 05B10, 05B25

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Colouring Kirkman triple systems

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Joint work with: Nicholas Cavenagh, Peter Danziger and David Pike

Abstract

A δ-colouring of a Steiner triple system S is an assignment of δ colours to its points so that no triple has all its points of the same colour. The chromatic number of S is the minimum number of colours δ such that S admits a δ-colouring. While colourings of Steiner triple systems have been widely studied (in particular, it is known that there exists a δ-chromatic STS(v) for every sufficiently large admissible order v), much less is known regarding colourings of Kirkman triple systems. In this talk, we show that for every integer $\delta \geq 3$, there exist infinitely many δ-chromatic Kirkman triple systems. Moreover, in the case $\delta = 3$, we give a complete existence result for 3-chromatic Kirkman triple systems.

Keywords: Colourings of designs, Weak colouring, Triple systems, Kirkman triple systems

MSC(2020): 05B07, 05C15

A Geometric Characterization of Unrefinable Partitions via the Keith-Nath Transformation

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Joint work with: Riccardo Aragona, Roberto Civino

Abstract

A partition into distinct parts is refinable if one of its parts a can be replaced by two different integers which do not belong to the partition and whose sum is a, otherwise the partition is unrefinable. We investigate the combinatorial structure of unrefinable partitions through their correspondence with numerical sets and Young diagrams. Building on the bijection introduced by Keith and Nath, we apply a general geometric criterion that links the unrefinability of a partition directly to the hook lengths of its associated Young diagram. This criterion provides a structural method for the characterization of any unrefinable partition. Using this general framework, we revisit the correspondence results between maximal unrefinable partitions and partitions into distinct parts, previously established using enumerative methods ([1],[2]). We provide alternative and purely combinatorial proofs of these bijections, focusing on the rigid symmetry structures of the Young diagrams.

Keywords: Integer partitions, Numerical semigroups, Young tableau

MSC(2020): 11P81, 05A17, 05A19

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An application of automata to partition identities

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Joint work with: Arne Meurman and Mirko Primc

Abstract

We interpret integer partitions as a formal language. We consider partitions satisfying certain restrictions as such a language and we then construct an automaton to describe it. The general theory of automata allows us to construct generating functions for the number of such partitions and a system of recurrences satisfied by them. Solving the system provides a new proof of a q-series identity of the Rogers-Ramanujan-type first discovered via Lie algebra representation theory.

Keywords: Integer partition; q-series; automaton.

References

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MSC(2020): 00X01, 01X02

Minimal codes from embedded point-line geometries

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Joint work with: Luca Giuzzi

Abstract

Let $\mathcal{C}(\Omega)$ be the linear code arising from a projective system Ω of $PG(V)$. Consider the point-line geometry $\Gamma = (\mathcal{P}, \mathcal{L})$ and a projective embedding $\varepsilon\colon \Gamma \to PG(V)$ of Γ. We show that the projective code obtained by taking as projective system $\Omega := \varepsilon(\mathcal{P})$ is minimal if the graph induced on the set $\Gamma \setminus \varepsilon^{-1}(H)$ by the collinearity graph of Γ is connected for any hyperplane H of $PG(V)$.

As an application, Grassmann codes, Segre codes, polar Grassmann codes of orthogonal, symplectic, hermitian type and codes arising from the point-hyperplane geometry of a projective space are minimal codes.

Keywords: Linear codes, minimal codes, projective embeddings

MSC(2020): 51E22, 51A50, 14M15

On the number of minimal and next-to-minimal weight codewords of certain toric codes.

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Joint work with: Nupur Patanker - SRM University-AP, India

Abstract

Let $\mathbb{F}_q$ be a finite field with q elements. Let $X := (\mathbb{F}_q^*)^s$ and let I_X be the vanishing ideal of X in $\mathbb{F}_q[\mathbf{t}] := \mathbb{F}_q[t_1, \ldots, t_s]$. One may check that, writing $n := |X|$ and $X := \{P_1, \ldots, P_n\}$, the evaluation map

$$\begin{aligned} \varphi : \mathbb{F}_q[\mathbf{t}]/I_X &\longrightarrow \mathbb{F}_q^n \\ f + I_X &\longmapsto (f(P_1), \ldots, f(P_n)) \end{aligned} \tag{1}$$

is an isomorphism

Definition 1. Let d be a positive integer such that $d \leq s$, let $L(d) \subset \mathbb{F}_q[\mathbf{t}]/I_X$ be the $\mathbb{F}_q$-vector subspace generated by

$$\{t_1^{a_1} \cdots t_s^{a_s} + I_X \mid a_i \in \{0, 1\} \ \forall\, i = 1, \ldots, s \text{ and } \sum_i a_i = d\}.$$

The toric code $C(d)$ is the image $\varphi(L(d))$.

The dimension and minimum distance of these codes have been determined by Jaramillo, Vaz Pinto and Villarreal in 2021. In this talk we will present results on the number of minimal weight codewords, when $3 \leq d < s$. We will also present results on the value of the next-to-minimal weight (i.e. the second lowest Hamming weight) and the number of next-to-minimal weight codewords, when $3 \leq d \leq \frac{s-2}{2}$ or $\frac{s+2}{2} \leq d < s$.

Keywords: Evaluation codes; toric codes; next-to-minimal weight.

MSC(2020): 00X01, 01X02

Quasi-optimal cyclic orbit codes

Chiara Castello

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Joint work with: Heide Gluesing-Luerssen, Olga Polverino, Ferdinando Zullo

Abstract

In 2008 Koetter and Kschischang highlighted the effectiveness of subspace codes for reliable transmissions in the context of random linear network coding. In [1] we focus on cyclic orbit codes, introduced in 2011 by Etzion and Vardy, as the subspace code analogue of classical linear codes in the Hamming metric. We focus on two aspects of cyclic orbit codes: invariants under equivalence and quasi-optimality. Regarding the first aspect, we establish a connection between the codewords of a cyclic orbit code and a certain linear set on the projective line. This allows us to derive new bounds on the parameters of the code. In the second part, we study a particular family of (quasi-)optimal cyclic orbit codes and derive a general existence theorem for quasi-optimal codes in even-dimensional vector spaces over finite fields of any characteristic. Thanks to the above construction, we prove the existence of quasi-optimal cyclic orbit codes for any parameter set, even in the case where the base field has order two and the dimension of the subspaces is half of the dimension of the ambient space, for which the existence of optimal codes is still an open problem. Finally, for our particular codes family we describe the automorphism groups under the general linear group and a suitable Galois group.

Keywords: Subspace code; cyclic orbit code, optimal orbit code, quasi-optimal orbit code.

References

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MSC(2020): 05B35, 05A30

The incidence matrix of a q-ary graph

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Joint work with: Relinde Jurrius, Netherlands Defence Academy

Abstract

This talk deals with q-ary graphs and their incidence matrix, with the aim to deduce q-matroids out of them [2]. We use this definition of q-ary graph, generalizing the strongly regular graph definition in [1].

Definition 1. Let $V = \mathbb{F}_q^m$ and let E be a set of 2-dimensional subspaces of V, the *edges*. Then (V, E) is a *q-ary graph* if for all $c_1, c_2 \in \mathbb{F}_q$ the *q-graph property* holds: If $\langle \mathbf{x}, \mathbf{y_1} \rangle$ and $\langle \mathbf{x}, \mathbf{y_2} \rangle$ are (adjacent) edges, then $\langle \mathbf{x}, c_1\mathbf{y_1} + c_2\mathbf{y_2} \rangle$ is also an edge.

Looking a the incidence matrix of a graph we distilled the properties we want to mirror in the q-analogue.

Definition 2. An incidence matrix of a q-ary graph in $\mathbb{F}_q^m$ is a matrix over $\mathbb{F}_{q^m}$ with m rows and a column for every edge. All columns are orthogonal to the vector $\mathbf{u} = [1, \alpha, \alpha^2, \dots, \alpha^{m-1}]^{\mathrm{T}}$, α being a primitive element of the field extension. The rank-support of a column is the corresponding edge.

We will explore some properties of such matrix, see examples of q-graphs and discuss on the current state of our investigation, in particular on connections with q-matroids and q-systems.

Keywords: q-ary graph, incidence matrix.

References

[1] M. Braun, D. Crnković, M. De Boeck, V.M. Crnković, A. Švob, "*q-Analogs of strongly regular graphs*", Linear Algebra Appl., **693** : 362–373, 2024.

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Addition-Deletion for SPOG Arrangements

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Joint work with: Takuro Abe

Abstract

Let $V = \mathbb{K}^\ell$ be a vector space over a field $\mathbb{K}$, and let $S = Sym(V^*) \cong \mathbb{K}[x_1, \ldots, x_\ell]$ be the polynomial ring. An *arrangement* $\mathcal{A}$ is a finite collection of linear hyperplanes in V. The *module of logarithmic derivations* is

$$\mathcal{D}(\mathcal{A}) = \{\theta \in \mathrm{Der}(S) \mid \theta(\alpha_H) \in \alpha_H S \text{ for all } H \in \mathcal{A}\},$$

where $\alpha_H \in S_1$ is a linear form defining H. The arrangement $\mathcal{A}$ is *free* with exponents $\exp(\mathcal{A}) = (d_1, \ldots, d_\ell)$ when $\mathcal{D}(\mathcal{A})$ is a free S-module. Fix a hyperplane $H_0 = \ker \alpha_0 \in \mathcal{A}$. We consider $\mathcal{A}' = \mathcal{A} \setminus \{H_0\}$ and $\mathcal{A}'' = \mathcal{A}^{H_0} = \{K \cap H_0 \mid K \in \mathcal{A}'\}$.

Definition 1 (Abe [1]). An arrangement $\mathcal{A}$ is **strictly plus-one generated (SPOG)** with $\mathrm{POexp}(\mathcal{A}) = (d_1, \ldots, d_\ell)$ and *level* d if $\mathcal{D}(\mathcal{A})$ has a minimal homogeneous generating set $\{\theta_1, \ldots, \theta_\ell, \phi\}$ with $\deg \theta_i = d_i$ and $\deg \phi = d$, and satisfying the single relation $\sum_i f_i\theta_i + \alpha\phi = 0$, where $f_i \in S, 0 \neq \alpha \in S_1$.

Our main results establish three addition-deletion theorems for SPOG arrangements, categorized by the relationship between the levels of $\mathcal{A}$ and $\mathcal{A}'$.

Theorem 2. *Let $d \neq d_i$ for all i. Suppose (1) $\mathcal{A}$ is SPOG with* $\mathrm{POexp}(\mathcal{A}) = (d_1, \ldots, d_\ell)$ *and level d, and (2) $\mathcal{A}'$ is SPOG with* $\mathrm{POexp}(\mathcal{A}') = (d_1, \ldots, d_i - 1, \ldots, d_\ell)$ *and level $d-1$. Then (3) $\mathcal{A}''$ is* **free** *with* $\exp(\mathcal{A}'') = (d_1, \ldots, \hat{d_i}, \ldots, d_\ell)$. *Moreover, if $D(\mathcal{A}'') \simeq D(\mathcal{A})/\alpha_0 D(\mathcal{A})$, then any two of (1)–(3) imply the third.*

Keywords: Hyperplane arrangements; addition-deletion-restriction; exponents.

References

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MSC(2020): 52C35,05E40,13D02

On the nullity of $\mathbb{T}$-gain graphs

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Abstract

Cactus graphs are important in discrete mathematics and network design because they offer a sparse, manageable structure that generalizes trees. They model complex, real-world systems like communication networks, electrical circuits, and genomes. Cycle-spliced graphs are special cactus graphs and the problem of their singularity seems interesting.

We consider the adjacency spectrum of cycle-spliced signed graphs Σ. It is studied in the literature for the relation between the nullity η (the multiplicity of the $0-$eigenvalue) and the cyclomatic number c. In particular, it is known that $0 \leq \eta(\Sigma) \leq c(\Sigma)+1$. In [Proyecciones2024] we characterize nonsingular cycle-spliced bipartite signed graphs. For cycle-spliced signed graphs Σ having only odd cycles, we show that $\eta(\Sigma)$ is 0 or 1. Finally, we compute the nullity of CSSGs consisting of at most three cycles.

In [Commun.Comb.Optim.(2025)] the study of the signed case has been extended to complex unit (or $\mathbb{T}$-gain) graphs Φ. We prove that $0 \leq \eta(\Phi) \leq c(\Phi)+1$. Moreover, we show that there is no cycle-spliced $\mathbb{T}-$gain graph Φ of any order with $\eta(\Phi) = c(\Phi)$ whenever there are no odd cycles whose gain has real part 0. We give examples of cycle-spliced $\mathbb{T}$-gain graphs whose nullity equals the cyclomatic number, and we show some properties of those graphs Φ such that $\eta(\Phi) = c(\Phi) - \epsilon$, $\epsilon \in \{0, 1\}$. A characterization is given in case $\eta(\Phi) = c(\Phi)$ when Φ is obtained by identifying a unique common vertex of 2 cycle-spliced $\mathbb{T}$-gain graphs Φ_1 and Φ_2. Finally, we compute the nullity of all $\mathbb{T}$-gain graphs Φ with $c(\Phi) = 2$.

At present the focus is on the study of cycle-spliced $\mathbb{T}$-gain graphs with an odd number of perfect matchings, and bipartite cycle-spliced graphs with a perfect matching and conditions on the gain of $B-$Type cycles.

Keywords: Nullity, cycle-spliced gain graphs, cyclomatic number

MSC(2020): 05C05, 05C50

MSC(2020): 05C57, 91A43

Cops Against a Cheating Robber

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Joint work with: D. Dyer and W. Kellough

Abstract

We consider a variation of the Cops and Robber game in which the cops and the robber move simultaneously yet the robber is able to react to the cops' moves [1]. As per usual with such models, our parameter of interest is the minimum number of cops that suffice to win on a given graph. We consider our parameter for planar and, in particular, bipartite planar graphs, and give bounds for strong and lexicographic products and some exact results. We also introduce a new parameter, the push number of a graph, and use it to compare this game with other variants.

Keywords: discrete-time graph processes, pursuit-evasion, Cops and Robber

References

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Graham conjecture on small sets in abelian groups

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Joint work with: Stefano Della Fiore, Mattia Fontana and Lluís Vena

Abstract

A famous conjecture of Graham asserts that every set $A \subseteq \mathbb{Z}_p \setminus \{0\}$ can be ordered so that all its partial sums are distinct. Although this conjecture was recently proved for sufficiently large primes by Pham and Sauermann in [2], it remains open for general abelian groups, even in the cyclic case $\mathbb{Z}_k$.

In this talk, we first show that a rectification argument (inspired by that of [1]), combined with a one-shot probabilistic approach, proves that the conjecture holds for any $A \subseteq \mathbb{Z}_k \setminus \{0\}$ such that

$$|A| \leq \exp\big(c(\log p)^{1/3}\big),$$

where p is the least prime factor of k, for a suitable constant $c > 0$.

We then turn to a recursive approach to study the sequenceability of subsets A in general abelian groups for small values of $|A|$. We prove that any subset $A \subseteq G \setminus \{0\}$ with $|A| \leq 20$ is sequenceable, improving the previously known bound $|A| \leq 9$. This bound is further improved to $|A| \leq 22$ for zero-sum subsets. Finally, in connection with the related CMPP conjecture, we show that zero-sum subsets without inverse pairs are sequenceable for $|A| \leq 23$.

Keywords: Sequenceability, Rectification

MSC(2020): 11B75

References

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[2] H. T. Pham, L. Sauermann. "*Graham's rearrangement conjecture*", available at `arXiv:2602.15797`.

q-ary distance-regular graphs

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Joint work with: Francesco Pavese and Andrea Švob

Abstract

In 2024, q-analogs of strongly regular graphs were introduced (see [1]). In this talk, we introduce the notion of q-analogs of distance-regular graphs, which generalizes the notion of q-analogs of strongly regular graphs. Further, we give some properties of q-analogs of distance-regular graphs.

Keywords: distance-regular graph; q-analog of graph; regular q-ary graph.

References

[1] M. Braun, D. Crnković, M. De Boeck, V. Mikulić Crnković, A. Švob. "*q-Analogs of strongly regular graphs*", Linear Algebra Appl., **693**:362–373, 2024.

MSC(2020): 05C12, 05C50, 05E30

Extending a result of Carlitz and McConnel to polynomials which are not permutations

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Abstract

Let f be a polynomial of $\mathbb{F}_q[x]$, where q is a power of the prime p. Denote by D the set of slopes determined by the graph of f, that is,

$$D = \left\{ \frac{f(x) - f(y)}{x - y} : x, y \in \mathbb{F}_q, x \neq y \right\}.$$

If D is contained in a multiplicative subgroup M of $\mathbb{F}_q^\times$, then by a result of Carlitz (1960) and McConnel (1963) it follows that $f(x) = ax^{p^k} + b$ for some $k \in \mathbb{N}$, $a \in M$, $b \in \mathbb{F}_q$. If $D \subseteq M$, then $0 \notin D$, and hence f is a permutation. If we assume the weaker condition $D \subseteq M \cup \{0\}$, then f need not be a permutation, but Sziklai conjectured that the same conclusion $f(x) = ax^{p^k} + b$ still holds. When the index $[\mathbb{F}_q^\times : M]$ is even, a result of Ball, Blokhuis, Brouwer, Storme and Szőnyi (1999), combined with a result of Göloğlu and McGuire (2014), proves the conjecture. We prove the following:

Theorem 1. *For some* $f \in \mathbb{F}_q[x]$, *assume* $\deg f \geq 1$. *If the size of* $D^{-1}D = \{d_1^{-1}d_2 : d_1 \in D \setminus \{0\}, d_2 \in D\}$ *is less than* $q - \deg f + 2$, *then* f *is a permutation of* $\mathbb{F}_q$.

Then we use this result to prove Sziklai's conjecture in full generality.

Keywords: direction problem; linearised polynomial; permutation polynomial

MSC(2020): 12E052

References

[1] B. Csajbók. "*Extending a result of Carlitz and McConnel to polynomials which are not permutations*", Finite Fields Appl., **108**:102683, 2025.

Packing designs with large block size

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Joint work with: Andrea Burgess, Daniel Horsley and Muhammad Tariq Javed

Abstract

Given positive integers v, k, t and λ with $v \geq k \geq t$, a packing design $\mathrm{PD}_\lambda(v, k, t)$ is a pair $(V, \mathcal{B})$, where V is a v-set and $\mathcal{B}$ is a collection of k-subsets of V such that each t-subset of V appears in at most λ elements of $\mathcal{B}$. When $\lambda = 1$, a $\mathrm{PD}_1(v, k, t)$ is equivalent to a binary code with length v, minimum distance $2(k - t + 1)$ and constant weight k. The maximum size of a $\mathrm{PD}_\lambda(v, k, t)$ is called the packing number, denoted $\mathrm{PDN}_\lambda(v, k, t)$.

We consider packing designs with k large relative to v. In this case, we extend the second Johnson bound to arbitrary λ and show that this bound is tight. Specifically, we prove that for a positive integer n, $\mathrm{PDN}_\lambda(v, k, t) = n$ whenever $nk - (t - 1)\binom{n}{\lambda+1} \leq \lambda v < (n + 1)k - (t - 1)\binom{n+1}{\lambda+1}$. We also extend this result to directed packings, by showing that if no point appears in more than three blocks, then the blocks of a $\mathrm{PD}_2(v, k, 2)$ can be directed so that no ordered pair occurs more than once.

Keywords: Packing Designs, Block Designs, Codes

MSC(2020): 05B40, 94B65

References

[1] Burgess, A.C., Danziger, P., Horsley, D. Javed, M.“ *Packing designs with large block size*”.Des. Codes Cryptogr. **94** (20) (2026)

Generalized Denniston Partial Difference Sets

James A Davis

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Joint work with: Sophie Huczynska, Laura Johnson, Shuxing Li, and John Polhill

Abstract

Denniston constructed a family of maximal arcs in projective planes of order 2^n. These can be used to construct projective two weight codes and hence partial difference sets. We will show in this talk that cyclotomy and quadratic forms allow for partial difference sets (but not maximal arcs) in groups of order p^{3n} for odd primes p. Moreover, we introduce a new family of partial difference sets that are based on the constructions.

Keywords: Relevant Keywords; Maximal Arcs, Partial Difference Sets

References

[1] Shuxing Li, James Davis, Sophie Huczynska, Laura Johnson, and John Polhill "*Strongly Regular Graphs with Generalized Denniston and Dual Generalized Denniston Parameters*", Combinatorial Theory, to appear, 2026.

MSC(2020): 00X01, 01X02

Neumaier graphs with exactly five eigenvalues

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Joint work with: Rhys J. Evans, Sergey Goryainov and Jack Koolen

Abstract

A *Neumaier graph* is an edge-regular graph with a regular clique. Such a graph is said to have parameters $(v, k, \lambda; e, s)$ if it is a k-regular graph on v vertices having a clique of size s such that every edge is contained in λ triangles and every vertex outside C is adjacent with exactly e vertices inside C. It was an open problem whether Neumaier graphs can exist with exactly five distinct eigenvalues. In the talk, the first examples of such graphs will be constructed. We hereby find 25 nonisomorphic examples all of which have parameters $(v, k, \lambda; e, s) = (48, 14, 2; 1, 4)$.

Keywords: Neumaier graphs, eigenvalues

MSC(2020): 05C35, 05C50, 05C69

The Service Rate Region of the Golay codes

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Joint work with: A. Ravagnani and E. Soljanin

Abstract

The binary and ternary Golay codes C_2 and C_3 are classical codes with remarkable combinatorial properties. We consider the design properties of these codes (and their extended versions C_2^{ext} and C_3^{ext}), and the impact they have for the Service Rate Region (SRR) of their generator matrices.

In the context of data storage, coding has emerged as a powerful technique to design optimal redundancy strategies, and the SRR is a polytope in $\mathbb{R}^k_{\geq 0}$ that describes the performance of different codes [1].

In this talk we will introduce the necessary tools to describe some of our main results, such as the following [2].

Theorem 1. *The SRR of C_3^{ext} is the 6-dimensional polytope $\sum_{i=1}^6 x_i \leq 4$.*

Our analysis allows us to also describe the properties of C_3^{ext} as a Private Information Retrieval (PIR) code.

Theorem 2. *C_3 is a 4-PIR code.*

Similar results for the binary Golay code will be discussed.

Keywords: Golay Code, Service Rate Region, Recovery System, Design, Private Information Retrieval

MSC(2020): 94B05, 94B25

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MSC(2020): 14H36

Algebraic curves with a large cyclic automorphism group

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Joint work with: Massimo Giulietti and Marco Timpanella

Abstract

The Hurwitz bound on the size of the $\mathbb{K}$-automorphism group $\mathrm{Aut}(\mathcal{C})$ of an algebraic curve $\mathcal{C}$ of genus $g \geq 2$ defined over an algebraically closed field $\mathbb{K}$ of zero characteristic is $|\mathrm{Aut}(\mathcal{C})| \leq 84(g-1)$. In positive characteristic, algebraic curves can have many more automorphisms than expected from the Hurwitz bound. There even exist algebraic curves of arbitrarily large genus g with more than $16g^4$ automorphisms.

There are better bounds for the size of certain types of groups. For instance, back in 1987 Nakajima showed that if G is an abelian subgroup of $\mathrm{Aut}(\mathcal{C})$, then $|G| \leq 4g+4$. For G a cyclic group, in the complex case $|G| \leq 4g+2$ and a complete characterization of algebraic curves over $\mathbb{C}$ with an automorphism of order at least $2g+1$ was given by Irokawa and Sasaki [1]. In particular, $\mathcal{C}$ is either a hyperelliptic curve or a quotient of the Fermat curve of degree $|G|$ by a cyclic group of order $|G|$. In arbitrary characteristic only the prime order case has been thoroughly investigated by Homma and, more recently, by Arakelian and Speziali.

In this talk, we will discuss whether Irokawa-Sasaki result holds also in positive charactheristic. The possibile occurrence of wild ramification, that is, of p-elements in G fixing a point of $\mathcal{C}$ makes this question rather intriguing.

Keywords: Algebraic curves; Positive characteristic; Automorphism groups

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A perfect code on the Schreier graphs of an automaton group

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Joint work with: Giuseppe Marino and Alessandro Neri

Abstract

The so-called Tangled Odometers group is a group generated by a three state automaton, acting by automorphisms on the ternary rooted tree and preserving its level structure. For each $n \geq 1$, the group action on the n-th level of the tree is described by the n-th Schreier graph, whose vertices can be naturally identified with the elements of the vector space $\mathbb{F}_3^n$. On this sequence of self-similar graphs, we explicitly construct a perfect 1-error-correcting code, proving that it is unique and linear. Our proofs make extensive use of the group structure which is intrinsic in the graph. The decoding process can be described both in terms of the action of the group generators, and by means of the adjacency matrix of the graph.

Keywords: Error-correcting code; Automaton group; Ternary rooted tree; Schreier graph; Linear code; Perfect code on a graph.

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MSC(2020): 05C12, 05C69, 20E08, 94B05, 94B25

MSC(2020): 14G50, 14M15, 94B27

Minimum weight codewords of Schubert codes

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Abstract

We fix a prime power q and two integers ℓ and m with $1 \leq \ell \leq m$. Let V_m be a $m-$dimensional vector space over the finite field $\mathbb{F}_q$ with an ordered basis $\mathcal{B}$. For any $\alpha \in I(\ell, m) := \{\alpha = (\alpha_1, \dots, \alpha_\ell) \in \mathbb{Z}^\ell : 1 \leq \alpha_1 < \dots < \alpha_\ell \leq m\}$ the *α-th Schubert subvariety of* the Grassmanian $G(\ell, V_m)$ with respect to the basis $\mathcal{B}$, is denoted by $\Omega_\alpha(\ell, V_m, \mathcal{B})$. The corresponding linear codes are called *Schubert codes*, and we denote their dimension by k_α. In [2], the authors conjectured that the minimum-weight codewords of Schubert codes are given by *Schubert decomposable* hyperplanes. Let $e_\alpha(\ell, m) := \max\{|\Pi \cap \Omega_\alpha(\ell, V_m, \mathcal{B})| : \Pi$ is a hyperplane of $\mathbb{P}^{k_\alpha - 1}\}$. In this talk, we show that

Theorem 1. *Let $q > q_0(\ell) = \frac{2^{\frac{1}{\ell-1}}}{2^{\frac{1}{\ell-1}}-1}$. For $\alpha \in I(\ell, m)$ and any hyperplane Π_α in $\mathbb{P}^{k_\alpha - 1}$, we have $|\Pi_\alpha \cap \Omega_\alpha(\ell, V_m, \mathcal{B})| \leq e_\alpha(\ell, m) := |\Omega_\alpha(\ell, V_m, \mathcal{B})| - q^{\delta(\alpha)}$. Moreover, the bound is attained if and only if Π_α is Schubert Decomposable.*

As a consequence, we show that the minimum weight codewords of Schubert codes are precisely the Schubert decomposable elements when q is sufficiently large.

Keywords: Schubert Subvarieties, Grassmann varieties, Schubert Codes.

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COMBINATORICS 2026
Naples, Italy, 25-29 May 2026

Steiner triple systems with many Veblen points

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Joint work with: Agota Figula, Mario Galici

Abstract

We studied Steiner triple systems by means of their associated Steiner loops, using a classic algebraic technique, that is, we reduced their structure to that of suitable normal subloops and the corresponding quotient loops.

In particular, the set of Veblen points turns out to be a Steiner triple subsystem, isomorphic to $\mathrm{PG}(d,2)$. The whole Steiner loop, in this case, is a Schreier extension of its center by the corresponding quotient loop, and it can be thoroughly described. This method is applied in [2] to classify (respectively, enumerate) STSs of order 19 (resp. 27 and 31), containing Veblen points. We set a threshold for the maximum number of Veblen points in a non-projective STS $\mathcal{S}$, culminating in the following result: if $2^n < |\mathcal{S}| < 2^{n+1}$, and if $\mathcal{S}$ contains at least 2^{n-3} Veblen points, then $\mathcal{S} \equiv \mathrm{PG}(n-1,2)$.

Recursive methods for constructing "products" of STSs are well. However, only one of these. coincides with the extension provided by our more general construction, the one corresponding to a *projective hyperplane*, a topic first studied by Teirlinck and later by Doyen, Hubaut, and Vandensavel.

Keywords: Steiner triple systems; Steiner loops; Veblen points; Schreier extensions.

MSC(2020): 05B07, 20N05, 1E10

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MSC(2020): 94B05, 94B27

Higher Order MDS Codes

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Abstract

One of the most important subjects in error-correcting code theory is the study of bounds relating the dimension of a code, its length, and its minimum distance. The most fundamental bound is the Singleton bound, and codes attaining this bound are called maximum distance separable (MDS) codes.

Three generalizations of the MDS property have been introduced by ([1], [2], [3]), using list decoding, algebraic independence and zero patterns of generator matrices. These notions were shown to be equivalent, allowing us to speak about "higher order MDS codes", denoted by MDS(L), where MDS(2) coincides with the classical notion of MDS codes.

There are two main contributions in this talk. The first is a proof of the equivalence between maximally recoverable tensor codes and higher order MDS codes. The second is the study of explicit constructions of MDS(3) codes via projective systems.

Keywords: MDS codes, list decoding, tensor codes, projective geometry

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Circular sorting in the alternating group

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Joint work with: Eric Swartz and Nicholas J. Werner

Abstract

The symmetric group S_n is generated by transpositions, and problems of sorting permutations using transpositions are well studied. In recent work, Adin, Alon, and Roichman [1] studied the related problem of sorting n points on a circle, and gave a formula for the maximum number of adjacent swaps required. This is equivalent to the number of adjacent transpositions required to transform any cyclic permutation (which can be viewed as an equivalence class of permutations in S_n) into the trivial cyclic permutation $[(1, 2, \ldots, n)]$. The case in which non-adjacent swaps are allowed was also considered in [1], and Bastide, Bishnoi, Groenland, Gijswijt, and Joshi [2] gave new lower bounds and provided algebraic constructions for permutations that require many swaps.

In this work, we consider an analogous question in the alternating group A_n, which is generated by 3-cycles. That is, using 3-cycles instead of transpositions, what is the maximum number of steps required to sort a cyclic permutation in the alternating group? We give formulas and bounds for this number depending on the residue class of n modulo 4.

Keywords: Sorting, alternating group, even permutations, cyclic permutations

MSC(2020): 05A05, 68P10

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Eigenvalues of the trilinear forms graph.

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Joint work with: Eimear Byrne

MSC(2020): 05C25,05C50,05E20,15A33,15A72,11T71.

Abstract

The connections between graph theory, and more generally association schemes, and coding theory were established by Philippe Delsarte for the Hamming metric and rank-metric codes [1]. The Hamming and rank-metric spaces can be seen as Cayley graphs generated by words of weight one. The metrics considered then coincide with the geodesic distances of these distance-regular graphs. We focus on a generalisation of this framework to the space of tensors over a finite field, endowed with the tensor-rank as a metric. This space corresponds to the Cayley graph generated by rank-one tensors. The adjacency spectrum of this non-distance-regular graph can be expressed with the rank distribution of the rank-metric codes generated by these tensors. We then study the applications of the result, and derive bounds on the dimension of tensor-rank metric codes using the eigenvalue method [2].

Definition 1. Let (n_1, n_2, n_3) be a tuple of positive integers. Denote by $G = \mathbb{F}_q^{n_1 \times n_2 \times n_3}$ the group of 3-tensors. For each $x \in G$, we denote by $\mathrm{ss}_3(x)$ the third contraction space of x, the space defined by $\mathrm{ss}_3(x) = \mathrm{im}\, m_3(x, \cdot) \subseteq \mathbb{F}_q^{n_1 \times n_2}$, where m_3 is the $\mathbb{F}_q$-bilinear map $m_3 : (a \otimes b \otimes c, v) \in G \times \mathbb{F}_q^{n_3} \mapsto a \otimes b(c \cdot v)$.

Theorem 2. *Denote by $S = \{u_1 \otimes u_2 \otimes u_3 : u_i \in \mathbb{F}_q^{n_i} \setminus \{0\}\}$ the set of rank one tensors. The eigenvalues of* $\mathrm{Cay}(G, S)$ *are integers and given by*

$$\lambda_x = |S| + q^{n_1+n_2+n_3}(q-1)^{-2}\left(-1 + q^{-\dim \mathrm{ss}_3(x)} W_{\mathrm{ss}_3(x)}(1, q^{-1})\right), \quad x \in G,$$

where $W_{\mathrm{ss}_3(x)}(X, Y)$ is the rank-weight enumerator of the rank-metric code $\mathrm{ss}_3(x)$.

Keywords: Cayley graph; eigenvalues; tensors; eigenvalue method; coding theory; rank-metric

References

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A cyclic flat embedding theorem for transversal q-matroids

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Abstract

Cyclic flats form a common structural invariant of both matroids and q-matroids, determining these objects through their weighted lattices of cyclic flats. In this talk we discuss an exploitation of this perspective that establishes a correspondence between matroids and a subclass of q-matroids that we call coordinate q-matroids.

Our main result is a cyclic flat embedding theorem showing that the cyclic flat structure of a transversal matroid is preserved under this correspondence. This provides a mechanism for transferring structural properties from matroid theory to the q-matroid setting. As an application, we show that nested q-matroids are transversal and therefore representable; a result not previously known. Furthermore, we discuss that due to the analogous cyclic flat structures of matroids and q-matroids under binary operations, we may generate large classes of representable q-matroids via cyclic flat embedding.

Keywords: q-transversals; q-matroids; cyclic flats; representability

MSC(2020): 05B35, 94B05

The Flag-Transitive and Point-Imprimitive Symmetric (v, k, λ) Designs with $v < 100$

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Joint work with: Alessandro Montinaro

Abstract

A $2-(v, k, \lambda)$ design $\mathcal{D} = (\mathcal{P}, \mathcal{B})$ consists of a set $\mathcal{P}$ of v points and a collection $\mathcal{B}$ of k-subsets of $\mathcal{P}$, called blocks, such that every pair of distinct points is contained in exactly λ blocks. A *flag* is an incident point–block pair. A group $G \leq \mathrm{Aut}(\mathcal{D})$ is *flag-transitive* if it acts transitively on the set of flags; in particular, G is transitive on both points and blocks. The group G is called *point-imprimitive* if it preserves a nontrivial partition of $\mathcal{P}$.

In this talk, we present a complete classification of the flag-transitive point-imprimitive symmetric 2-(v, k, λ) designs with $v < 100$. Besides the previously known examples with $\lambda \leq 10$, the complementary design of $\mathrm{PG}_5(2)$, and the 2-design $\mathcal{S}^-(3)$ constructed by Kantor in [1], we obtain exactly two non-isomorphic 2-$(64, 28, 12)$ designs. These designs were first constructed computationally by AbuGhneim in [2] as developments of $(64, 28, 12)$-difference sets. Independently of [2], we provide a purely theoretical construction and prove that their full automorphism group is flag-transitive and point-imprimitive.

Keywords: 2-designs; flag-transitive designs; imprimitive permutation groups.

MSC(2020): 20B25, 05B05, 05B25.

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Toward a unified theory for common affine roots of general sets of multivariate polynomials

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Abstract

For univariate polynomials over arbitrary field the degree gives an upper bound on the number of roots (factor theorem) and as a related result for any finite point-set one can construct a polynomial of degree equal to the cardinality having all the points as roots (interpolation theorem). Tao noted in [1] that the theory of multivariate polynomials is not yet sufficiently matured to provide similar theorems with an equally simple relation between them. In the present paper we argue that for general multivariate polynomials the right measure for the size of the polynomial should not be the degree, but the leading monomial. In this setting the footprint bound becomes a natural enhancement of the factor theorem providing a bound on the number of common roots of general multivariate polynomials which is sharp for all finite Cartesian product point-sets. As our main contribution, by using methods from the theory of error-correcting codes we establish a natural formulation of the interpolation theorem to the case of common roots of multivariate polynomials. In short the two theorems reduce to the same result, but for dual spaces, establishing the unification requested in [1].

Keywords: Affine roots, footprint bound, interpolation, multivariate polynomials

MSC(2020): 05E40, 12E05

References

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Concise $3 \times 3 \times 3$ tensors

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Joint work with: Michel Lavrauw

Abstract

A $3 \times 3 \times 3$ tensor over a finite field $\mathbb{F}_q$ can be viewed projectively as a point of $\mathrm{PG}(26, q)$, where the rank-one tensors form the Segre variety. Contraction spaces of concise $3 \times 3 \times 3$ tensors correspond to planes contained in $\mathrm{PG}(\mathbb{F}_q^3 \otimes \mathbb{F}_q^3)$ and their orbits under the natural group action have strong links with finite geometry and semifield theory. About a decade ago, lines in this space were classified in [3] using a geometric approach. More recently, substantial progress has been made on the classification of *(partially) symmetric* $3 \times 3 \times 3$ tensors, which correspond to planes in the space of the Veronese surface [1], where the geometry is more rigid and additional structure is available. In this talk we discuss the splitting and merging behaviour (following [2]) of orbits of concise $3 \times 3 \times 3$ tensors inside the full tensor space. The problem is well grounded in existing work, yet naturally opens up new and largely unexplored directions.

Keywords: Segre Variety; Tensor product; Finite geometry

MSC(2020): 05B25, 05E20, 15A69, 51E20

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Thresholds for Tic-Tac-Toe on Finite Affine Spaces

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Joint work with: Luca Bastioni and Javier Lobillo Olmedo

Abstract

We study a strong positional game on the finite affine space $\mathbb{F}_q^m$. Two players alternately claim points, and the first player to occupy all points of an affine n-subspace wins. For fixed n and q, we study the threshold $T(n, q)$ in the ambient dimension m which separates drawing instances from first-player winning instances.

The talk will present the basic structure of this threshold. By strategy stealing, the second player never has a winning strategy; by monotonicity, once the first player wins in dimension m, he also wins in all larger dimensions. Finiteness of $T(n, q)$ follows from the affine/vector-space Ramsey theorem of Graham, Leeb and Rothschild. Lower bounds come from Maker-Breaker methods, including the Erdős-Selfridge criterion, and from explicit geometric pairing strategies. In particular, for every $n \geq 2$ and every prime power q, we prove $T(n, q) \geq n + 2$.

In the binary case we obtain explicit estimates by a direct argument. A Fourier-analytic bound for subsets of $\mathbb{F}_2^m$ with no affine 2-plane, combined with an inductive lifting argument, gives

$$T(n, 2) \leq 2^{n+1} \qquad \text{for every } n \geq 1.$$

Together with the Erdős-Selfridge lower bound, this places $T(n, 2)$ between roughly $2^n/(n + 1)$ and $2 \cdot 2^n$. We also discuss small cases related to Tic-Tac-Toe on finite affine planes, such as $T(1, q) = 2$ for $q \in \{2, 3, 4\}$ and $T(2, 2) = 4$, as well as the conjecture that, for every prime power q, one has $T(n, q) \leq C_q q^n$ for some constant C_q.

MSC(2020): 91A46, 05B25, 05D10, 51E20

Keywords: Positional games; finite affine spaces; Maker-Breaker games; affine Ramsey theory

Two new recursive constructions of regular symmetric Hadamard matrices with constant diagonal

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Joint work with: Willem Haemers, Elena Konstantinova and Honghai Li

Abstract

A k-regular graph on v vertices is called a *divisible design graph* (DDG for short) with parameters $(v, k, \lambda_1, \lambda_2, m, n)$ if its vertex set can be partitioned into m classes of size n such that any two vertices from the same class have λ_1 common neighbours and any two vertices from different classes have λ_2 common neighbours [1]. A divisible design graph is called *thin* if the classes of the partition from the definition have size 2. There is a remarkable interplay between thin divisible design graphs and symmetric weighing matrices [1, Theorem 4.3 and Theorem 4.4].

In this talk, as an illustration of the interplay, we present two new recursive constructions of regular symmetric Hadamard matrices with constant diagonal or, equivalently, two new recursive constructions of strongly regular graphs.

Keywords: divisible design graph; Hadamard matrix; weighing matrix; strongly regular graph

MSC(2020): 05B20, 05E30, 05B05

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On the classification of Dillon's APN hexanomials

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Joint work with: Daniele Bartoli, Pantelimon Stănică

Abstract

Almost perfect nonlinear (APN) functions play a fundamental role in cryptography, particularly in the design of block ciphers and stream ciphers where they provide optimal resistance against differential cryptanalysis. In 2006, Dillon [1] suggested investigating a specific class of hexanomials (polynomials with six terms) as potential candidates for APN functions. These functions, defined over $\mathbb{F}_{q^2}$ where $q = 2^n$, have the form:

$$F(x) = x(Ax^2 + Bx^q + Cx^{2q}) + x^2(Dx^q + Ex^{2q}) + x^{3q}.$$

Using algebraic number theory and methods on algebraic varieties over finite fields, we establish necessary conditions on the coefficients A, B, C, D, E that must hold for the corresponding function to be APN.

Keywords: Finite fields; permutation polynomials, varieties; irreducible components.

MSC(2020): 11G20, 11T06, 12E20, 14Q10.

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Extremal bipartite edge-girth-regular graphs constructed as bi-coset graphs

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Joint work with: Robert Jajcay

Abstract

An *edge-girth-regular* egr(n, k, g, λ)-graph Γ is a k-regular graph of order n and girth g in which every edge is contained in λ distinct girth-cycles, i.e., cycles of length g. The graphs of smallest order among all edge-girth-regular graphs for a given triple of parameters (k, g, λ) are called *extremal*. Similarly, the smallest bipartite graphs among all edge-girth-regular graphs for given parameters (k, g, λ), g even, are called *extremal bipartite edge-girth-regular*.

It is natural to seek extremal edge-girth-regular graphs within the class of edge-transitive graphs. In this context, bi-coset graphs provide a useful family, as they are known to be edge-transitive.

In the talk we provide three infinite families of extremal edge-girth-regular graphs that were constructed as bi-coset graphs corresponding to matrix groups: one from special linear groups, one from Heisenberg groups, and one from the affine linear groups. The corresponding parameters are egr$(2(p^2-1), p, 6, p^3-4p^2+6p-3)$, egr$(2p^2, p, 6, p^3-4p^2+5p-2)$ and egr$(2p, p-1, 4, (p-2)(p-3))$, respectively.

Keywords: Girth-cycles; edge-girth-regular graphs, bi-coset graphs.

MSC(2020): 05C35

The resultant method in higher dimensions

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Abstract

Stability results play an important role in Galois geometries. In a typical stability theorem we have a certain class of structures (e.g. arcs, ovals, blocking sets, etc.) and some result classifying the *extremal* objects of the class (the smallest or largest ones). Then a stability theorem assures that an *almost extremal* object of the class, e.g. a point set of size *close* to the extremal value, can be obtained *only* by slight modifications of an extremal, classified object (e.g. deleting or adding some points from/to it).

The famous resultant method, developed by Szőnyi and Weiner, became very fruitful and resulted in many stability theorems in the last two decades. This is a method based on bivariate polynomials associated to point sets; the results of algebraic shape are then translated back to the original geometric language. In this talk we show the generalization of the method for the multidimensional case using multivariate polynomials and apply it to *Rédei polynomials* to prove a high dimensional analogue of a result of Szőnyi-Weiner. We also present the "few or many" argument, which is the key tool for many stability results. Finally we show how these tools can be used to prove a stability theorem for blocking sets of the n-dimensional projective space.

Keywords: Resultant method, Rédei polynomial, partial blocking sets

MSC(2020): 51E20, 05B25

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Cocliques and the Chromatic Number of generalized Kneser graphs

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Abstract

We consider the generalized Kneser graph $\Gamma_q(n, T)$, whose vertices are the flags of type T of PG(n, q), where two vertices are adjacent if they are opposite as flags. Over the last years cocliques of these graphs have been studied for various values of n and T. If there is a stability result for the cocliques, often the chromatic number of the graph is also known, see for example [1, 2, 4]. We discuss a recent result [3] on the cocliques of $\Gamma_q(2n, \{n-1, n\})$, together with [2] this determines the chromatic number of $\Gamma_q(2n, \{n-1, n\})$ for all $n \geq 2$. Determining the chromatic number in the case $n = 1$ seems non-trivial, even though all cocliques are characterized. This is discussed as an open problem.

Keywords: Chromatic Number, Coclique, Erdős-Ko-Rado

MSC(2020): 05C69, 05C35

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A result on Zarankiewicz' Problem

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Joint work with: András Károly Bognár, Hanna Egyházi

Abstract

The Zarankiewicz number $Z_{s,t}(m,n)$ is defined to be the largest number of edges a bipartite graph $G = (A, B; E)$ with $|A| = m$, $|B| = n$ can have if it does not contain s vertices in A and t vertices in B that span a $K_{s,t}$ subgraph. Illés and Krarup [1] conjectured that if $m = n$, then any $K_{2,2}$-free bipartite graph $G = (A, B; E)$ with $|A| = |B| = n$ and $|E| = Z_{2,2}(n, n)$ is almost regular; that is, the degrees of its vertices take only two different, consecutive values. A weakened form of this conjecture is that for all n there exists a $K_{2,2}$-free bipartite graph $G = (A, B; E)$ with $|A| = |B| = n$ and $|E| = Z_{2,2}(n, n)$ in which A or B is almost regular. The proofs of well-known upper bounds (such as the Kővári–Sós–Turán Theorem Roman's bound) seem to support this conjecture. In the talk, we combine a proof from [2] with a construction based on finite projective planes to show that the weakened conjecture fails for infinitely many values of n.

Keywords: Zarankiewicz numbers; extremal graph theory; finite projective planes.

MSC(2020): 05C35, 05B25

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[2] M. Chen, H.-L. Fu, J. Jiang, Y.-H. Lo, Y. Miao. "*New bounds on $\bar{2}$-separable codes of length 2*", Designs, Codes and Cryptography, 74(1):31–40, 2013.

Combinatorial Properties of Discrete Balls

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Abstract

In 1977, Ahlswede and Katona [1] proposed the isoperimetric problem of finding *minimum average distance codes (MADCs)*. These are codes with minimum average (Hamming-) distance among all binary codes of a given size and length. In 2002, Kündgen [2] conjectured that for every size and length there is at least one MADC that is a discrete ball. Given a center $c \in \mathbb{R}^n$ and a radius $r \in \mathbb{R}$, a *discrete ball* is defined as

$$B(c,r) = \{x \in \{0,1\}^n : \|x-c\|_1 \leq r\}.$$

In this talk, I will show that *every* MADC is a discrete ball, solving the conjecture. Furthermore, I will show that the feasible set of the well known Knapsack problem is always a discrete ball. This is especially interesting because discrete balls are similar to matroids. It is well known that the Greedy algorithm returns an optimal solution if the feasible set of a Knapsack instance is a matroid. Using the similarities between discrete balls and matroids, I will present a new class of Knapsack instances for which the Greedy algorithm always returns an optimal solution.

Keywords: Discrete ball; Minimum average distance; Knapsack problem

MSC(2020): 05D05, 90C27

References

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Array Codes from Perfect One-Factorizations

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Joint work with: Barbara Maenhaut

Abstract

B-codes are a class of low-density parity-check (LDPC) array codes over $\mathbb{F}_2$ with constant weight structure and applications in reliable storage and communication systems. It is a known result that B-codes with certain parameters are in one-to-one correspondence with perfect one-factorizations (P1Fs) of complete graphs (see [2, 1]). In this work, we extend this correspondence to the setting of bipartite graphs. Since perfect one-factorizations are known to exist more abundantly in the bipartite case, this generalization yields new constructions of B-codes. In particular, we obtain optimal B-codes for parameter sets that are not accessible via the classical construction from complete graphs. Furthermore, we investigate the relationship between these new codes and those arising from P1Fs of complete graphs. We characterize when B-codes derived from bipartite P1Fs correspond to punctured versions of codes obtained from complete graphs, thereby clarifying the structural connections between the two constructions. Our results provide new combinatorial insights into the interplay between graph factorizations and array code design, and expand the range of parameters for which optimal B-codes are known.

Keywords: array codes, B-codes, graph matchings, perfect one factorizations

References

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MSC(2020): 05C70,05C51,94B05,94B25

MSC(2020): 57M15, 57Q70, 05C69, 05E45, 05E18.

From Graphs to Complexes

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Joint work with: M. Bayer, M. Denker, R. Rowlands, S. Sundaram, and L. Xue

Abstract

At the intersection of graph theory and algebraic topology, simplicial complexes arising from graphs have become an active area of research with many interesting connections. This talk focuses on cut complexes and total cut complexes, two classes of graph complexes that we introduced [1, 2], motivated by interactions among graph theory, topology, and commutative algebra.

For a graph G and an integer k, the k-cut complex $\Delta_k(G)$ is the simplicial complex whose facets are the complements of disconnected k-vertex sets. The motivation for this project comes from famous Fröberg's theorem, which connects graph theory, squarefree monomial ideals, and the combinatorial structure of simplicial complexes. In particular, Fröberg's theorem says that $\Delta_2(G)$ is shellable if and only if graph G is chordal. We generalize Fröberg's theorem and study how structural properties of graphs are reflected in the combinatorics and topology of the complexes $\Delta_k(G)$. We give sufficient conditions for k-cut complexes to be shellable and describe how common graph operations affect shellability. We also determine combinatorial properties and homotopy types of cut complexes for various important graph classes.

Keywords: graph complex; chordal graph; independent set; shellability; homotopy.

References

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[2] M. Bayer, M. Denker, M. Jelić Milutinović, R. Rowlands, S. Sundaram, L. Xue. "*Total cut complexes of graphs*", Discrete Comput. Geom., **73**: 500–527, 2025.

What is the q-analogue of a binary code?

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Abstract

An important class of matroid is that of binary matroids. These are equivalent to linear codes over $\mathbb{F}_2$ in the Hamming metric. Moreover, they generalise graphs, and many results on binary matroids are inspired by graph theory. From a combinatorial point of view binary matroids (and codes) are of interest because the incidence matrix of a combinatorial object will also give a binary matroid (and code), and the structure of the combinatorial object can be used to derive results about the matroid (and code).

This talk discusses the q-analogue of binary matroids. It will by no means answer this question, but give some suggestions about directions of study and possible applications. We refer to the presentation of [1] for more motivation for this question.

Keywords: binary matroid, incidence matrix, q-analogue

MSC(2020): 00X01, 01X02

References

[1] Michela Ceria, Relinde Jurrius. "*The incidence matrix of a q-ary graph*", `arXiv:2508.19964`, 2025.

Almost Locally Equitable Colourings of BIBDs

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Joint work with: Andrea C. Burgess, David A. Pike

Abstract

In this talk, we study ℓ-colourings of (v, k, λ)-BIBDs where within each block, one colour is absent and each of the $\ell - 1$ other colours appear exactly $\frac{k}{\ell-1}$ times. We give necessary conditions for such colourings to exist. We show how Hadamard matrices, affine planes, and twin prime powers can be used to construct such coloured BIBDs.

Keywords: colouring; balanced incomplete block design; Hadamard matrices, affine planes, twin prime powers

MSC(2020): 05B05, 05C15

A general result for latin squares with disjoint subsquares

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Abstract

A subsquare is a subarray of a latin square which is itself a latin square. Two subsquares are considered to be disjoint if they share no rows, columns or symbols. Given orders $h_1 \geq h_2 \geq \cdots \geq h_k$ and $n \geq h_1 + \cdots + h_k$, is it possible to find a latin square of order n with pairwise disjoint subsquares of orders $h_1, \ldots, h_k$?

When there are only a few subsquares, it is not too difficult to completely answer this question. For an arbitrary number of subsquares, this question remains frustratingly unsolved. In this talk, I will discuss an easier general result: that when n is at least h_1 more than the necessary $h_1 + \cdots + h_k$, such a latin square always exists. Constructing these latin squares involves everything but the kitchen sink: transversals, trades, outline squares and some interesting sequences.

Keywords: latin square, subsquare

MSC(2020): 05B15

Multiple blocking sets in PG$(2, p^n)$

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Joint work with: Joint work with B. Csajbók, E. M. Robin, B. Sógor, S. Wang, E. Williams

Abstract

A K-fold blocking set of the Desarguesian plane PG$(2, p^n)$, p prime, is a set of points meeting each line of the plane in at least K points. The minimum size of such sets is of interest for numerous reasons; however, even the minimum size of nontrivial blocking sets (1-fold blocking sets not containing a line) is an open question for $n \geq 5$ odd. For $n > 1$ the conjectured lower bound for this size is $(p^n + p^{n(s-1)/s} + 1)$, where s is the least prime divisor of n.

Based on the works of Sziklai in [1] and the fact that the disjoint union of K blocking sets is a K-fold blocking set, it can be conjectured that the minimum size of a K-fold blocking set in PG$(2, p^n)$ is $K(p^n + p^{n(s-1)/s} + 1)$, when $p^{n/s}$ is large enough w.r.t. K. For even n, the partition of the plane into Baer subplanes gives a K-fold blocking set of this size; however, for odd n, the existence of such sets is unsolved in most cases.

The main result in my talk is the following theorem:

Theorem 1. *For each prime p and integer $n > 1$, if s is the least prime divisor of n, then there exist K-fold blocking sets of size $K(p^n+p^{n(s-1)/s}+1)$ in* PG$(2, p^n)$ *for $K = 2, 3$.*

Keywords: Multiple blocking sets; linear sets

MSC(2020): 51E21

References

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On the $((3n)_4)$-configurations of Kárteszi

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Joint work with: Gábor Gévay and Tomaž Pisanski

Abstract

An (n_k)-configuration $(\mathcal{P}, \mathcal{L})$ is a set $\mathcal{P}$ of n points and a set $\mathcal{L}$ of n lines such that each point lies on exactly k lines, and each line contains exactly k points. The configuration is geometric, topological, or combinatorial depending on whether lines are considered to be straight lines, pseudolines (simple closed curves) or just combinatorial lines. Configurations are closely related to finite geometries and extremal graph theory.

In 1964, *Ferenc Kárteszi* proved a theorem in real geometry that gives rise to a series of geometric 4-configurations $\mathrm{K}(n; \ell, m)$. In this talk, we explore some properties of the Kárteszi configurations and in particular show that $\mathrm{K}(7; 2, 3)$ is isomorphic to the famous (21_4)-configuration of *Grünbaum* and *Rigby*, which was only presented in 1990.

Keywords: geometric configuration, celestial configuration, Grünbaum–Rigby configuration, Kárteszi configuration, regular n-gon.

MSC(2020): 51A20, 51A45, 51E30, 05B30, 01A60.

The intersection distribution and its uses in finite geometry

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Joint work with: Sophie Huczynska and Maura Paterson

MSC(2020): 51E15, 11T06, 05B25

Abstract

Many interesting objects studied in finite geometry, for example arcs and ovals, are defined through their intersection with lines. In [1], Li and Pott introduce the *intersection distribution*, counting the sizes of intersections of a set with all lines of an affine or projective plane. They use it as a tool to study the behaviour of polynomials over finite fields. They also give classifications and connections to structures like Kakeya sets and Steiner triple systems.

In this talk, we show how to use connections to diverse mathematical areas like algebraic curves and enumeration of irreducible polynomials to establish new results about the intersection distribution. These alternative viewpoints lead to short and concise proofs of some results in [2] as well as new results. We study the effects of the maximum non-zero entry on the intersection distribution and give constructions using cyclotomy. This talk will also include a live demonstration of how to use GAP and the FinInG package to work with the intersection distribution and solve open problems posed in [1].

Keywords: finite projective plane; intersection distribution; finite field polynomials;

References

[1] S. Li and A. Pott, "*Intersection distribution, non-hitting index and Kakeya sets in affine planes*", Finite Fields Their Appl., **66**:101691, 2020.

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A superlinear improvement on 2-blocking sets in AG$(3, p)$

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Abstract

In the affine space $S = \mathrm{AG}(n, q)$, let $b_d(n, q)$ denote the minimum size of a d-*blocking set*, that is, a set of points $B \subseteq S$ intersecting every affine subspace of S of codimension d in at least one point. It is well-known that $b_1(n, q) = 1 + n(q-1)$, and this bound is attained by taking the union of the n coordinate axes.

Similarly, one can obtain a 2-blocking set in $\mathrm{AG}(3, q)$ of size $3q^2 - 3q + 1$ by taking the union of the three coordinate planes, $\{(x, y, z) : xyz = 0\}$. However, this construction is not optimal. Previously it was shown [1] in the $q = p$ prime case that

$$2p^2 + (\sqrt{2} - 1)p - 2 \leq b_2(3, p) \leq 3p^2 - 4p + 2\sqrt{p} + 1,$$

where the upper bound arises from modifying said construction in $\Theta(p)$ points. Note that $B \subseteq \mathrm{AG}(3, q)$ is a 2-blocking set if and only if its complement $\overline{B}$ avoids complete affine lines.

In this talk, the author presents a new upper bound, obtaining the following result by making a larger modification to the previous constructions:

Theorem 1. $b_2(3, p) \leq 3p^2 - \frac{1}{8}p^{3/2} + O(p)$.

Keywords: blocking sets, affine geometry

References

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MSC(2020): 51E21, 05B25

MSC(2020): 05B05

A new Steiner 3-design

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Joint work with: Michael Kiermaier and Alfred Wassermann

Abstract

We present a previously unknown Steiner design with parameters $S(3, 6, 42)$. It was discovered in a computational study of Steiner 3-designs with small parameters, by extending $S(2, 5, 41)$ designs [1]. The new design does not extend to a 4-design while preserving any of its automorphisms.

The full automorphism group of the new 3-design has order 432 and acts in two orbits on the set of points. It is isomorphic to AGL$(2, 3)$, suggesting a connection with the affine plane of order 3. We will discuss a purely geometric description of the new design.

Keywords: Steiner system; block design; automorphism group.

References

[1] M. Kiermaier, V. Krčadinac, A. Wassermann. "*Steiner 3-designs as extensions*", preprint, 2025. `https://arxiv.org/abs/2509.23483`

Tops in the Graph of Two-Dimensional Simplex Codes, Nuclei and Near Orthomorphisms

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Abstract

We study tops (maximal cliques defined by planes) in the graph of q-ary simplex codes of dimension two, considered as an induced subgraph of the Grassmann graph. A top consists of all 2-dimensional simplex codes contained in a fixed 3-dimensional subspace, provided this family forms a maximal clique in the simplex code graph. We prove that there is a one-to-one correspondence between the elements of such a top and the set of nuclei of the associated $(q+1)$-point projective system in $\mathrm{PG}(2,q)$. Here, a nucleus of a point set in the projective plane is a point through which all tangents to the set pass. This geometric interpretation provides a precise structural criterion for the existence of tops: they occur exactly when the corresponding set of nuclei contains three non-collinear points.

Using known results on nuclei in finite projective planes, we derive general structural properties of tops. Moreover, we present an explicit method for computing all tops of $\Gamma^s(2,q)$ via near-orthomorphisms of the multiplicative group of $\mathbb{F}_q$. An orthomorphism of a finite group G is a is a bijection $\theta : G \to G$ such that the map $x \mapsto x^{-1}\theta(x)$ is also bijective. A near-orthomorphism excludes an element from domain and an element from range of θ.

Keywords: graph of simplex codes, nuclei, near orthomorphisms

MSC(2020): 05B25, 51E20

Decompositions of the wreath product of two hamiltonian decomposable directed graphs into hamiltonian cycles

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Abstract

A (directed) graph is *hamiltonian decomposable* if it admits a decomposition into (directed) hamiltonian cycles. The question of existence of a decomposition into hamiltonian cycles has been considered for various classes of graphs. For example, it is known that the wreath (lexicographic) product and the strong product of two hamiltonian decomposable graphs is also hamiltonian decomposable. However, for directed graphs, much less is known. In this talk, we consider a conjecture of Alspach et al. [1] that stipulates that the wreath product of two hamiltonian decomposable directed graphs G and H, denoted $G \wr H$, is also hamiltonian decomposable. Ng [2] confirmed this conjecture when $|V(G)|$ is odd. We will address the case $|V(G)|$ is even and confirm this conjecture for all but two non-trivial cases. We also identify one non-trivial family of exceptions.

Keywords: Wreath product, Hamiltonian decomposition, directed graphs.

MSC(2020): 05C70, 05C20

References

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COMBINATORICS 2026
Naples, Italy, 25-29 May 2026

Divisibility and Quasidivisibility of Arcs in PG(r, q)

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Joint work with: Assia Rousseva

Abstract

Let $\mathcal{P}$ be the pointset of PG(r, q). An (n, w)-arc in PG(r, q) is a multiset $\mathcal{K} : \mathcal{P} \to \mathbb{N}_0$ such that $\mathcal{K}(\mathcal{P}) = n$, $\mathcal{K}(H) \leq w$ for every hyperplane H, and $\mathcal{K}(H_0) = w$ for some hyperplane H_0. An (n, w)-arc in PG(r, q) is called divisible with divisor Δ if $\mathcal{K}(H) \equiv n \pmod{\Delta}$ for every hyperplane H. An (n, w)-arc in PG(r, q) is called t-quasidivisible with divisor Δ if $\mathcal{K}(H) \equiv n, n+1, \cdots, n+t \pmod{\Delta}$ for every hyperplane H. If $t = 1$ such arcs are called just quasidivisible. By Ward's theorem [1], arcs in PG$(k-1, p)$ associated with Griesmer codes satisfying $w \equiv n \pmod{p^e}$ are divisible with divisor p^e. In this talk we prove the following divisibility results.

Theorem 1. *Let $\mathcal{K}$ be a Griesmer (n, w)-arc in PG$(k-1, q)$, where*

$$n - w = q^{k-1} - \lambda_{k-2}q^{k-2} - \cdots - \lambda_r q^e,$$

with $0 \leq \lambda_i < q$, and $e \geq 2$. Then $p^2 q^{e-2}$ is a divisor of $\mathcal{K}$.

Theorem 2. *Let $\mathcal{K}$ be a Griesmer (n, w)-arc in PG$(k-1, p)$, p prime, with*

$$n - w = sp^{k-1} - \lambda_{k-2}p^{k-2} - \cdots - \lambda_1 p - 1,$$

with $0 \leq \lambda_i \leq p-2$ for $i = 1, \cdots, k-2$. Then $\mathcal{K}$ is quasidivisible and hence extendable to a divisible Griesmer arc with divisor p.

Keywords: divisible arcs, quasidivisible arcs, divisible codes, Griesmer codes, extendable arcs

MSC(2020): 51E20, 51E21, 94B65

References

[1] H. N. Ward. "*Divisibility of codes meeting the Griesmer bound*", J. Combin. Theory Ser. A, **83**:79–93, 1998.

On the dimension of the space generated by maximum rank distance codes

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Abstract

Given positive integers m, m' with $m \leq m'$, a rank-metric code $\mathcal{C}$ in $\mathbb{F}_q^{m\times m'}$ with minimum distance $d = m - t + 1$ is called a maximum rank distance (MRD) code if it attains the Singleton-like bound. This talk explores the $\mathbb{Q}$-vector space spanned by the characteristic vectors of all such MRD codes. We demonstrate that the exact dimension of this generated space is $q^{mm'} - \sum_{k=1}^{t} v_k$, where v_k represents the k-th valency of the bilinear forms scheme. Our techniques involve determining the eigenvalues of the Gram matrix UU^T formed by the incidence matrix U of the MRD codes. We will briefly discuss the interactions between MRD codes and the association scheme of bilinear forms, utilizing generalized Krawtchouk polynomials and properties of q-binomial coefficients to classify the zero eigenvalues of the Gram matrix.

Keywords: MRD codes; bilinear forms scheme; dimension; eigenvalues.

MSC(2020): 94B25, 05E30

Perfect difference families, perfect systems of difference sets and their applications

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Joint work with: Tao Feng, Xiaomiao Wang, Menglong Zhang

Abstract

Let v be a positive odd integer. A (v, k, λ)-perfect difference family (PDF) is a collection $\mathcal{F}$ of k-subsets of $\{0, 1, \ldots, v-1\}$ such that the multiset $\bigcup_{F \in \mathcal{F}} \{x - y : x, y \in F, x > y\}$ covers each element of $\{1, 2, \ldots, (v-1)/2\}$ exactly λ times.

Perfect difference families are introduced in the 1970s by Bermond, Kotzig, and Turgeon to address spacing problems in radio astronomy antennas. While the case for block size $k = 3$ was settled early on, determining the existence of $(v, 4, 1)$-PDFs has stood as a major open problem for nearly 50 years, known as Bermond's conjecture [2]. Our main result is the following.

Theorem 1. [1] *Let v be a positive odd integer. A $(v, 4, \lambda)$-PDF exists if and only if $\lambda(v-1) \equiv 0 \pmod{12}$, $v \geq 13$, and $(v, \lambda) \notin \{(25, 1), (37, 1)\}$.*

This result fully confirms Bermond's conjecture and extends it to general index λ. Furthermore, it yields new constructions for optimal OOCs, DNA origami GOCs, and graceful French windmill labelings, among others.

Keywords: perfect difference family; perfect system of difference sets.

MSC(2020): 05B05

References

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MSC(2020): 05C10, 05C75, 05C69, 05C07, 52B05

Common neighbours in planar graphs

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Abstract

For every positive integer n, we find a complete classification for planar graphs according to the collection of numbers of common neighbours for every n-tuple of distinct vertices. Our results expand the literature on planar graphical degree sequences, that have recently been the object of renewed attention. Here we completely settle the version with no multiplicities of the vast problem of planar graphical n-degree sequences.

Keywords: Planar graph; Vertex neighbours; Common neighbours; Classification; Vertex degree; Degree sequence

References

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[2] Maffucci, "*Classification of polyhedral graphs by numbers of common neighbours*", ARXIV:2508.01349.

On the Šoltés problem for the Kirchhoff index of a graph

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Joint work with: T. Došlić and K. K. Gottwald

Abstract

The Kirchhoff index $Kf(G)$ of a connected graph G is the sum of resistance distances between all vertex pairs. A vertex is good if its removal does not change $Kf(G)$. We emphasize C_5 is the only known graph in which all vertices are good and study relaxed variants focusing on graphs with many good vertices. We show that Laplacian integral graphs are natural candidates for containing a large number of good vertices, as the problem reduces to solving nontrivial Diophantine equations derived from spectral conditions. We construct infinite families of graphs with prescribed proportions of good vertices, including cases where these proportions approach rational and irrational limits. Additionally, we provide results for unicyclic and cactus graphs. These findings highlight a connection between spectral graph theory and number theory and suggest new directions for further research.

Keywords: resistance distance; Kirchhoff index; Laplacian matrix.

References

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MSC(2020): 05C12, 05C09, 05C38, 05C05, 05C90

MSC(2020): 05C70

On the existence of factors intersecting sets of cycles in regular graphs

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Joint work with: J. Goedgebeur, G. Mazzuoccolo, J. Renders, L. Toffanetti, I. H. Wolf

Abstract

A recent result by Kardoš, Máčajová and Zerafa [1] related to the famous Berge-Fulkerson Conjecture implies that given an arbitrary set of odd pairwise edge disjoint cycles, say $\mathcal{O}$, in a bridgeless cubic graph, there exists a 1-factor intersecting all cycles in $\mathcal{O}$ in at least one edge. This remarkable result opens up natural generalizations in the case of an r-regular graph G and a t-factor F, with t and r being positive integers. In this work, we start the study of this problem by proving necessary and sufficient conditions on G, t and r to assure the existence of a suitable F for any possible choice of the set $\mathcal{O}$. First of all, we show that G needs to be 2-connected. Under this additional assumption, we highlight how the ratio $\frac{t}{r}$ seems to play a crucial role in assuring the existence of a t-factor F with the required properties by proving that $\frac{t}{r} \geq \frac{1}{3}$ is a further necessary condition. We suspect that this condition is also sufficient, and we confirm it in the case $\frac{t}{r} = \frac{1}{3}$, generalizing the case $t = 1$ and $r = 3$ proved by Kardoš, Máčajová, Zerafa, and in the case $\frac{t}{r} = \frac{1}{2}$ with t even. Finally, we provide further results for the case where even cycles are included.

Keywords: Regular graph; factor; cycle.

References

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Uniquely Normal Graphs

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Joint work with: Rong-Xia Hao, Yilun Luo and Edita Máčajová

Abstract

In this talk, we first give a brief review of normal edge-colourings of cubic graphs and their connection to the Petersen Colouring Conjecture. This famous conjecture is relevant because it implies other well-known conjectures, like the Cycle Double Cover and the Berge-Fulkerson conjectures.

A normal 5-edge-colouring of a cubic graph is a proper 5-edge-colouring where, for each edge, the set formed by the colour of the edge itself and the four edges incident to its endpoints contains either exactly five different colours (in which case the edge is called rich), or exactly three different colours (in which case the edge is called poor).

The main part of the talk is about a special family of graphs called uniquely normal graphs. These are graphs where every normal edge-colouring gives the same division of edges into rich and poor. We study some specific types of uniquely normal graphs and examine their structure and colouring properties. As an additional result, we use these graphs to construct an infinite family of counterexamples to a recent conjecture by Sedlar and Škrekovski.

Keywords: Cubic graph, Normal Edge Coloring, Petersen Coloring

MSC(2020): 05C15, 05C70

References

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MSC(2020): 20N05, 05B15.

On the Hadamard quasigroup product

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Joint work with: R. M. Falcón and P. Vojtěchovský

Abstract

The Hadamard quasigroup product is an operation on arrays that was recently introduced in [1]. Given a Latin square L, the Hadamard quasigroup product between two arrays A and B is the array whose (i, j)-th entry is $L(a_{ij}, b_{ij})$.

In this talk we first investigate some basic algebraic properties of this product, and we highlight a connection between this operation and orthogonal arrays [2]. We then show that the action of this operation on arrays induces a geometric structure, naturally leading to a notion of orientability of quasigroups. We further investigate this concept in relation with left involutive and left distributive quasigroups.

Keywords: Hadamard product; Latin Squares.

References

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Some new Circular External Difference Families

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Joint work with: Andrea C. Burgess and Tommaso Traetta

Abstract

Circular External Difference Families (CEDFs) are a variation of external difference families that were recently introduced as a tool for constructing non-malleable threshold schemes. A (v, m, ℓ, λ)-CEDF over a group G is a sequence of m disjoint ℓ-subsets whose cyclic pairwise difference multisets cover each nonzero element of G exactly λ times.

Most work has focused on the case $\lambda = 1$, so that $v = m\ell^2 + 1$, and G a cyclic group. Cyclic CEDFs are known to exist whenever m is even, while they cannot exist when both m and ℓ are odd. The case where m is odd and ℓ is even is much less understood.

We study cyclic $(v, m, \ell, 1)$-CEDFs in this remaining case. We construct cyclic $(4m + 1, m, 2, 1)$-CEDFs for every odd $m > 1$, giving two constructions that yield different structural patterns and hence inequivalent CEDFs. We also prove the existence of cyclic $(3\ell^2+1, 3, \ell, 1)$-CEDFs for every even $\ell \geq 2$. Our approach views the blocks as arithmetic progressions and analyzes how their steps control the difference structure.

Keywords: Circular external difference family, AMD code

MSC(2020): 05B10, 94A62

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Involution Spaces: Emerging Structures, Unified Constructions, and Applications

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Abstract

We present a unified combinatorial and algebraic framework for the study of self-dual vectorial bent functions ([2]) that combine maximal nonlinearity with strong spectral symmetry ([3]). The main approach relies on a new key notion of *involution spaces* ([1]), i.e., $\Pi_m^{(s)} = \{\sum_{i=1}^{s} c_i\pi_i : c_i \in \mathbb{F}_2\}$, where $\pi_1, \ldots, \pi_s$ are permutations of $\mathbb{F}_{2^m}$ satisfying intrinsic involutive symmetry. Based on a central result proving that involution spaces provide a direct mechanism for enforcing self-duality: for any (r,t)-function G with $r+t=s$, the vectorial function $H(x,y) = (\mathrm{Tr}_1^m(x\pi_1(y)), \ldots, \mathrm{Tr}_1^m(x\pi_t(y))) + G\left(\mathrm{Tr}_1^m(x\pi_{t+1}(y)), \ldots, \mathrm{Tr}_1^m(x\pi_s(y))\right)$, is a self-dual vectorial bent $(2m,t)$-function whenever the permutations $\pi_1, \pi_2, \ldots, \pi_s$ generate an involution space, we explain how this framework yields unified constructions that extend sevral classical families and develop new combinatorial objects whose components generate linear codes.

Keywords: Bent function, Self-dual bent function, Involution space, Partial Spreads

MSC(2020): 06E30, 94A60, 94D10

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On the Etzion and Silberstein conjecture for block Ferrers diagrams

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Joint work with: Marco Calderini and Alessandro Neri

Abstract

Ferrers diagrams rank-metric codes were introduced by Etzion and Silberstein in 2009 with the purpose of finding well-behaving subspace codes. We provide a construction for codes on block Ferrers diagrams by inserting on the diagonals of the associated matrices codewords of maximum sum-rank distance (MSRD) codes. Therefore, we define MSRD-constructible pairs and prove that, for these pairs, our construction produces optimal codes, with a restriction on the field size. Finally, we take a step forward in dropping the dependency on the field size by reducing block Ferrers diagrams to block triangular diagrams under the assumption of MSRD-constructibility.

Keywords: Ferrers diagram rank-metric codes, Etzion-Silberstein conjecture.

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MSC(2020): 11T71, 94B05, 94B60

On some applications of the theory of Drinfeld modules

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Joint work with: Luca Bastioni, Mohamed Darwish, Mihran Papikian

Abstract

In this talk we apply the theory of Drinfeld modules to construct rank metric codes, which are important information-theoretical objects. In particular, we focus on constructions of MRD codes and optimal rank metric codes with rank locality.

Keywords: Rank Metric Codes, Drinfeld Modules, Number Theory

MSC(2020): 11T06

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On dual adjacency matrix (candidate) and (weakly) uniform structure

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Joint work with: B. Fernández, R. Maleki, and Š. Miklavič.

Abstract

In this talk, we investigate the connection between two properties that a bipartite graph can possess: Q-*polynomiality* and *uniform structure*. To do so, we first introduce the concept of a *dual adjacency matrix candidate* and define a *weakly uniform structure* by slightly relaxing the standard conditions for a uniform structure [1]. We then establish a one-to-one correspondence between these two concepts, as our main result shows [2]:

Theorem 1. *A bipartite graph* Γ *admits a dual adjacency matrix candidate with respect to* x *and corresponding parameters* β, ρ *if and only if* Γ *admits a weakly uniform structure with respect to* x*; in particular, for* $\beta = 2$*, the latter weakly uniform structure coincides with an actual uniform structure.*

Keywords: Uniform property, dual adjacency matrix, Q-polynomial property.

MSC(2020): 05E99, 05C50

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Existence of three anti-cocircular truncated Möbius planes and strength-4 covering arrays

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Joint work with: Kianoosh Shokri and Brett Stevens

Abstract

A strength-t *covering array*, denoted by $CA(N; t, k, v)$, is an $N \times k$ array over a v-set such that in any t-set of columns, each t-tuple occurs at least once in a row. Two projective (affine) planes with the same point set are *orthogoval* if the common intersection of any two lines, one from each, has size at most two. A pair of orthogoval projective planes can be used to construct a strength-3 covering array $CA(2q^3-1; 3, q^2+q+1, q)$ [1, 2]. The present work extends this result to construct arrays of strength 4. The plane sections (circles) of an ovoid in $PG(3, q)$ are the blocks of a 3-$(q^2+1, q+1, 1)$ design, called a *Möbius plane* of order q. For q an odd prime power, we prove the existence of three truncated Möbius planes, such that for any choice of three circles, one from each plane, their intersection size is at most three. From this, we construct a strength-4 covering array $CA(3q^4-2; 4, \frac{q^2+1}{2}, q)$, for any odd prime power q, which improve bounds on the covering array tables for $q \geq 11$.

Keywords: covering array; projective geometry.

MSC(2020): 05B20, 05B25

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One-weight codes in the sum-rank metric

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Joint work with: Ferdinando Zullo

Abstract

One-weight codes, in which all nonzero codewords share the same weight, form a highly structured class of linear codes with deep connections to finite geometry. While their classification is well understood in the Hamming and rank metrics—being equivalent to (direct sums of) simplex codes—the sum-rank metric presents a far more intricate landscape. In this work, we explore the geometry of one-weight sum-rank metric codes, focusing on three distinct classes. First, we introduce and classify *constant rank-list* sum-rank codes, where each nonzero codeword has the same tuple of ranks, extending results from the rank-metric setting. Next, we investigate the more general *constant rank-profile* codes, where, up to reordering, each nonzero codeword has the same tuple of ranks. Although a complete classification remains elusive, we present the first examples and partial structural results for this class. Finally, we consider one-weight codes that are also MSRD (Maximum Sum-Rank Distance) codes. For dimension two, constructions arise from partitions of scattered linear sets on projective lines. For dimension three, we connect their existence to that of special 2-fold blocking sets in the projective plane, leading to new bounds and nonexistence results over certain fields.

Keywords: Sum-rank metric code; One-weight code; Linear set; Simplex Code

MSC(2020): 11T71; 51E20; 11T06; 94B05

References

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Linear type vertex-transitive strongly regular graphs

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Joint work with: R. Bailey and V. Smaldore

Abstract

A *two-graph* is a pair $\mathcal{T} = (V, T)$, where T is a set of unordered triples of a vertex set V, such that every (unordered) quadruple from V contains an even number of triples from T. Given a simple graph $\Gamma = (V, E)$, the set of triples T of the vertex set V, whose induced subgraph has an odd number of edges, forms the *associated two-graph* of Γ. Finite two-graphs with a 2-transitive automorphism group have been classifed by Taylor [2]. The class of linear type two-graphs has $\mathrm{Aut}(\mathcal{T}) \cong P\Sigma L(2, q)$, where $q \equiv 1 \pmod 4$.

In this talk, we present the construction of a vertex-transitive

$$\mathrm{srg}\left(q+1, \frac{q \pm \sqrt{q}}{2}, \frac{(\sqrt{q} \pm 1)^2}{4} - 1, \frac{(\sqrt{q} \pm 1)^2}{4}\right),$$

whose associated two-graph is of linear type.

Keywords: Strongly Regular Graphs; Two-graphs; $PSL(2, q)$

MSC(2020): 05E30

References

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Secant size distributions in projective planes

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Joint work with: Zsuzsa Weiner

Abstract

Given a point set S in a projective plane of order q, each line ℓ determines a secant size $|S \cap \ell|$. We study how balanced this secant-size distribution can be, in other words, how many lines must share the same secant size.

This problem is related in spirit to the Szemerédi-Trotter theorem which claims that the number of lines with at least k points in a planar n-set of points is at most $O(n^2/k^3 + n/k)$, hence it provides indirect control on large secant classes via incidence limits. It is also related to the concept of legitimate colorings (of Alon and Füredi). Note also, that the direction problem concerns a similar question: in a point set S of $AG(2, q)$ of size kq, a non-determined direction is such that the points of S are equidistributed on the lines corresponding to the given direction.

Definition 1. Let $L_k(S)$ denote the set of k-secants of the set $S \subseteq \Pi_q$ and $s_m(S)$ denote the largest multiplicity of secant size in a line-intersection distribution, i.e., $s_m(S) := \max_k\{|L_k(S)|\}$.

We determine the the minimum size of the largest secant class $s_m(S)$ over all point sets in Π_q up to a small multiplicative constant.

Theorem 2. *For any set $S \subseteq \Pi_q$, the most common secant size appears at least $\Omega(q^{3/2})$ times. This bound is best possible, in particular,*

$$\frac{2}{3\sqrt{3}}q^{3/2} \leq \min_{S \subseteq \Pi_q} s_m(S) \leq (1 + o(q^{-\frac{1}{2}}))\sqrt{\frac{2}{\pi}}q^{3/2}.$$

We also discuss explicit constructions that are asymptotically close to optimal, and point out a link between the upper-bound constructions and character-sum estimates.

A knapsack McEliece-based public key cryptosystem

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Joint work with: J. Gómez-Torrecillas and J. F. Lobillo

MSC(2020): 94A60, 11T71

Abstract

Knapsack-based cryptosystems comprise one of the earliest families of public key encryption schemes and played a prominent role in the historical development of public key cryptography. However, despite their connection to the NP-complete subset sum problem, many classical knapsack constructions were shown to be vulnerable, in particular to lattice-based attacks. In contrast, the McEliece cryptosystem has remained a candidate for post-quantum cryptography standardization due to its long-standing resistance to both classical and quantum attacks.

In this talk, we propose a public key encryption scheme that can be viewed as a knapsack variant with a McEliece-inspired structure, aiming to reduce the weakness of knapsack-type systems under lattice reduction attacks. Analogously to the decoding of general Goppa codes, decryption is based on the use of a truncated version of the extended Euclidean algorithm. At the same time, similarly to knapsack-type cryptosystems, it takes advantage of the extensive existing libraries for fast integer arithmetic operations, resulting in very efficient key-generation and encryption–decryption algorithms. The security relies on an NP-complete problem, suggesting resistance to known attacks by quantum computers, a property shared with the McEliece cryptosystem. Unlike typical knapsack-based systems, our proposal can operate over non-binary alphabets, which provides additional security against low-density attacks.

Keywords: Public key encryption scheme, knapsack cryptosystem, McEliece cryptosystem

Motzkin paths and flag codes

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Joint work with: Clementa Alonso-González

Abstract

Motzkin paths represent many mathematical objects from different contexts with combinatorial flavor. In this talk, we exhibit the appearance of these paths in the setting of *flag codes*. A flag code is a set of *flags*, i.e., sequences of nested subspaces of a vector space over a finite field, with prescribed increasing dimensions. The *flag distance* is defined as the sum of the respective *subspace distances* and can be obtained in different ways, which considerably complicates the manipulation of these codes. We define the set of Motzkin paths associated with a flag code. This new invariant allows us to characterize some important families of flag codes and to extract relevant information about them. In particular, it gives us a direct way to compute the maximum possible number of combinations behind a prescribed value of the minimum distance.

Keywords: Motzkin paths; Motzkin numbers; flag codes; flag distance.

MSC(2020): 94B99, 05A17

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Flow resistance to resistance ratio in cyclically 5-edge-connected snarks

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Joint work with: Davide Mattiolo and Silvia Pagani

MSC(2020): 05C15, 05C21

Abstract

Snarks are bridgeless cubic graphs that do not admit a proper 3-edge-coloring.

In this talk, I will present a joint result with Mattiolo and Pagani that provides a positive answer to a recent question posed by Allie, Máčajová, and Škoviera [1] about the existence of cyclically 5-edge-connected snarks in which the ratio between the flow resistance and the resistance can be arbitrarily large.

We recall that a graph G is called *cyclically k-edge-connected* if it does not contain any cyclic edge-cut of cardinality less than k. The *resistance* $r(G)$ of a cubic graph G is the minimum number of edges whose removal results in a 3-edge-colorable graph, while the *flow resistance* $r_f(G)$ is the minimum number of edges whose removal results in a graph admitting a nowhere-zero $\mathbb{Z}_2 \times \mathbb{Z}_2$-flow. Our main result is the following.

Theorem 1. *For every integer $n \geq 1$, there exists a cyclically 5-edge-connected snark H_n of order $40n+2$ such that $r(H_n) = 2$ and $r_f(H_n) = n$.*

Keywords: Flow resistance; Resistance; Cyclic edge-connectivity; Snark.

References

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The Neighbor Graph of Linear Complementary Dual (LCD) Codes

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Joint work with: J. de la Cruz, A.-L. Horlemann, C. Vela Cabello, W. Willems

Abstract

Linear complementary dual (LCD) codes—codes whose intersection with their duals are trivial—were first introduced by Massey[2] in 1992 and have subsequently garnered interest due to their applications to general coding theory, cryptography, and quantum error correction. In order to investigate the properties of these codes, we study the LCD neighbors of LCD codes, i.e., codes whose intersection is of co-dimension 1. We characterize when such a neighbor relationship exists corresponding to previously studied constructions used in the context of self-dual codes[1]. Subsequently, we build the neighbor graphs of LCD codes, i.e., graphs whose vertices consist of LCD codes with fixed length and dimension and whose edges represent a neighbor relation between two such LCD codes. These graphs are regular and can be decomposed into regular subgraphs corresponding to subclasses of LCD codes defined by code invariants. We calculate the regularity degree of these subgraphs and the biregularity degrees between them as well as investigate other graph properties of these neighbor graphs.

Keywords: Linear complementary dual codes, neighbors, regular graphs

MSC(2020): 94B05, 05C90

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On the density of Kravitz sets

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Joint work with: Vsevolod Lev, Máté Matolcsi, Dániel Varga

Abstract

At the problem session of the Edinburgh meeting on additive combinatorics (2024), Noah Kravitz asked how large a subset $A \subseteq \mathbb{F}_p$ can be such that $A+A-2A \neq \mathbb{F}_p$, where $A+A-2A = \{a_1+a_2-2a_3 \colon \; a_1, a_2, a_3 \in A\}$.

In the integer setting, Bukh [1] proved that for any finite set $A \subseteq \mathbb{Z}$, and any $\lambda_1, \ldots, \lambda_k \in \mathbb{Z}$ with $\gcd(\lambda_1, \ldots, \lambda_k) = 1$, one has $|\lambda_1 A + \cdots + \lambda_k A| \geq \left(\sum_{i=1}^{k} |\lambda_i|\right)|A| - o(|A|)$. Fiz Pontiveros [2] proved that the analogous estimate holds in $\mathbb{F}_p$, provided that the set A is small. For dense sets A, this may not be the case. As shown in [2], for any nonzero integer λ and $\varepsilon > 0$, there exists $\delta > 0$ such that the following holds: if p is a sufficiently large prime, then there exists a set $A \subseteq \mathbb{F}_p$ with $|A| \geq (1/2 - \varepsilon)p$ such that $|A + \lambda A| \leq (1 - \delta)p$.

In this talk, we prove the following result:

Theorem 1. *If $p > 3$ is a prime and $A \subseteq \mathbb{F}_p$ is a subset of size $|A| > \frac{2}{7}p$, then $A + A - 2A = \mathbb{F}_p$.*

Our proof uses a linear programming approach, but we will also discuss a purely combinatorial argument as well.

Keywords: additive combinatorics, linear programming, dilate, sumset

MSC(2020): 11B13, 11B75

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Decompositions of $C(n, \{1, 3\})$ into circuits

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Joint work with: Mariusz Meszka

Abstract

Definition 1. A *decomposition* of a graph G is a collection of edge-disjoint subgraphs $H_1, H_2, \ldots, H_t$ of G such that each edge of G belongs to exactly one of the subgraphs H_i.

Definition 2. For a positive integer n and a set $S \subseteq \{1, \ldots, \lfloor(\frac{n}{2}\rfloor)\}$ a *circulant graph* $C(n, S)$ is a graph $G = (V, E)$ such that $V = \mathbb{Z}_n$ and $E = \{\{u, v\} : \delta(u, v) \in S\}$ where $\delta(u, v) = min\{\pm|u - v| \pmod n\}$.

Inspired by the work of Bryant and Martin [1], who gave a complete solution to the problem of decomposing $C(n, \{1, 2\})$ into cycles, we examine the case when $S = \{1, 3\}$. Our main result is the necessary and sufficient condition for the decomposition of $C(n, \{1, 3\})$ into circuits of lengths from a specified list, which was obtained by applying the previous solution to the cycle decomposition problem of the considered graph.

Keywords: circulant graph, decomposition, circuit

MSC(2020): 05B30

References

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Cycle Structure of Feedback Linearly Extended Discrete Functions

Daniel Panario

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Joint work with: Claude Gravel and Hugo Teixeira

Abstract

Let q be a power of a prime and let $n > m \geq 0$ be integers. Let $\mathbb{F}_q$ be the finite field with q elements and $\mathbf{T} : \mathbb{F}_q^n \to \mathbb{F}_q^n$, $\mathbf{A} : \mathbb{F}_q^n \to \mathbb{F}_q^m$, and $\mathbf{B} : \mathbb{F}_q^n \to \mathbb{F}_q^{n-m}$ be full-rank linear transformations such that $\mathbf{AB}^t = \mathtt{0}$. For a function $f : \mathbb{F}_q^m \to \mathbb{F}_q^{n-m}$, Gravel and Panario [1, 2] define the function $F : \mathbb{F}_q^n \to \mathbb{F}_q^n$ as

$$x \mapsto \mathbf{T}(x + \mathbf{B}^{\mathrm{t}} f(\mathbf{A}x)). \tag{1}$$

The map F linearly extends the function f into a permutation over $\mathbb{F}_q^n$.

In this work, we study the cycle structure of particular cases of linearly extended discrete functions. We establish the different lengths of cycles appearing in the functional graph of F, correlating with the order of the eigenvalues of the transformation $\mathbf{T}$. In addition, we also determine ways to maximize either the number of cycles or length of each cycle in the graph associated with the map F.

Keywords: Iterations of functions; cycle decomposition; finite fields.

MSC(2020): 11T55, 15B33

References

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[2] C. Gravel and D. Panario. "*Revisiting linearly extended discrete functions*", Journal of Mathematical Cryptology, **18**, Article 20240010, 2024.

Four relations on the set of point-hyperplane anti-flags

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Joint work with: Antonio Pasini

Abstract

A point-hyperplane anti-flag of $\mathrm{PG}(n-1,\mathbb{F})$ is a pair of non-incident point and hyperplane. There are precisely four arrangements of two point-hyperplane anti-flags. We consider the corresponding relations on the set of such anti-flags and show that each of them can be recovered from any other except in one special case. If the field consists of two elements, then one of the relations cannot be used to recover each of the remaining three. This is related to a bijection between anti-flags and exterior points of the hyperbolic polar space which exists in this case.

Keywords: anti-flag, involution, polar space

MSC(2020): 51A10, 51A50

MSC(2020): 05B05, 05B10

On relative Heffter spaces

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Joint work with: L. Johnson and L. Mella

Abstract

Given a subgroup J of an abelian group G, a *Heffter space on* G *relative to* J is a resolvable configuration whose points form a half-set of $G \setminus J$ and whose blocks are all zero-sum in G. This concept simultaneously generalizes those of relative Heffter arrays and Heffter spaces introduced in [2] and in [1], respectively. The aim of the research on this topic is to constrcut relative Heffter spaces with largest possible degree.

In this talk we present two infinite families of relative Heffter spaces having large degree and satisfying the additional condition of being simple, obtaining, as a consequence, new results on globally simple relative Heffter arrays, on mutually orthogonal cycle decompositions and on biembeddings of cyclic cycle decompositions of the complete multipartite graph into an orientable surface.

Keywords: Heffter system; configuration

References

[1] M. Buratti, A. Pasotti. "*Heffter spaces*", Finite Fields Appl., **98**:102464, 2024.

[2] S. Costa, F. Morini, A. Pasotti, M. Pellegrini. "*A generalization of Heffter arrays*", J. Combin. Des, **28**(3):171–206, 2020.

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Clifford-like parallelisms in kinematic spaces arising from quadratic algebras

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Joint work with: S. Pianta

Abstract

In a series of three papers starting with [1], we first introduced the notion of *Clifford-like parallelisms* in the projective 3-space $\mathrm{PG}(3, F)$ over a commutative field F of any characteristic by means of *quaternion algebras*. Subsequently, we provided conditions for their existence and we described their properties and their group of automorphisms.

Here we present an extension of these results to the case of *double spaces* derived from *quadratic algebras* in characteristic not equal to 2, which are embedded into projective spaces (not necessarily of dimension 3) and endowed with two parallelisms. Building on H. Karzel's classification of these algebras, which includes quaternion algebras, we have obtained a geometric description of the Clifford parallelisms for each class and we have used these results to provide necessary and sufficient conditions for the existence of the new Clifford-like parallelisms, thus extending our results on quaternion algebras. Preliminary results on the automorphism groups will also be discussed.

Keywords: Clifford parallelisms; Clifford-like parallelisms; Kinematic spaces; Double spaces; Quadratic algebras.

MSC(2020): 51A15, 51J15

References

[1] H. Havlicek, S. Pasotti, and S. Pianta. "*Clifford-like parallelisms*", J. Geom., **110**(2), 18 pp, 2019.

[2] S. Pasotti, and S. Pianta. "*Clifford-like parallelism and quadratic algebras*", in preparation.

Flag Invariants of Rank Metric Codes

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Joint work with: Eimear Byrne & John Sheekey

Abstract

Finding structural properties of codes that remain invariant under equivalence is an active line of research due to the computational hardness of existing invariants, which act as distinguishers between equivalence classes of codes. Beyond initial considerations such as minimum distance and weight enumerators, one of the most well-studied invariants is the *generalised weights* of a code [1].

In this talk we introduce a new invariant for vector rank metric codes based on the support dimensions of complete flags of subcodes.

Definition 1. Given a flag $\mathcal{F}: \ \mathcal{F}_1 \subset \ldots \subset \mathcal{F}_k = C$ of the $[n,k]$ code $C \subseteq \mathbb{F}_{q^m}^n$, with $\dim(\mathrm{supp}_{\mathrm{rk}}(\mathcal{F}_i)) = f_i$. We define the *effective length vector of the flag*, $\mathfrak{E}(\mathcal{F}) := (f_1, \ldots, f_k)$, and the optimal vector with respect to an ordering $\preceq$ as

$$\mathfrak{E}_{flag,\preceq}(C) := \min_{\preceq}\{\mathfrak{E}(\mathcal{F}) \mid \mathcal{F} \text{ is a flag of } C\}.$$

We show that this is invariant under equivalence. We demonstrate that it is related to the generalised weights, but that they are both different and easier to compute than the generalised weights. We also relate the new invariants to the corresponding q-system of the code, and give various theoretical and computational results.

Keywords: rank-metric codes, code equivalence, complete flags, generalised weights, rank supports, q-system

References

[1] G. Marino, A. Neri, and R. Trombetti. Evasive Subspaces, Generalized Rank Weights and Near MRD codes. Discrete Mathematics, 346(12):113605, 2023.

MSC(2020): 51E20, 94B27,94B60

Old and new solutions of Kirkman's schoolgirl problem

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Abstract

We recall some of the "classical" solutions of Kirkman's schoolgirl problem in the literature, since the earliest ones in 1850, and present some of the more recent solutions. The most interesting and appealing ones are found among the *visual* solutions, that is, those arrangements that can be actually visualized by representing the 15 schoolgirls as suitable parts of a geometric object in the plane or in the 3-dimensional space.

Definition 1. The fifteen schoolgirl problem (T. P. Kirkman, 1850). Fifteen young ladies in a school walk out three abreast for seven days in succession: it is required to arrange them daily so that no two shall walk twice abreast.

Equivalently, the fifteen schoolgirl problem amounts to asking whether there exists a Kirkman triple system of order 15.

Keywords: Schoolgirl problem, Kirkman triple system, KTS.

MSC(2020): 05B07, 05B05, 01A55.

References

[1] G. Falcone, M. Pavone. "*Kirkman's tetrahedron and the fifteen schoolgirl problem*", Amer. Math. Month., **118**(10):887–900, 2011.

[2] M. Pavone. "*On the seven non-isomorphic solutions of the fifteen schoolgirl problem*", Discrete Math., **346**(6):113316, 2023.

[3] M. Pavone. "*Three optimal visual solutions of Kirkman's schoolgirl problem*" (submitted).

The automorphism groups of the symmetric $(15, 8, 4)$-designs

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Joint work with: Mark Pankov and Mariusz Żynel

Abstract

It is known that there are precisely five pairwise non-isomorphic symmetric $(15, 8, 4)$-designs. One of them is the design of points and hyperplane complements of $\mathrm{PG}(3, 2)$, whose automorphism group is $\mathrm{GL}(4, 2)$.

We determine the automorphism groups of the remaining four symmetric $(15, 8, 4)$-designs and describe their actions on points and blocks. The proof is computer-free and is based on point-line geometry.

Four of the five designs, including the design arising from $\mathrm{PG}(3, 2)$, are self-dual and correspond uniquely to equivalence classes of bijective transformations of Fano planes. These classes are determined by the number of lines mapped to lines. The fifth design is dual to one of them; consequently, the automorphism groups of these two designs coincide.

Keywords: symmetric block design; point-line geometry; Fano plane.

MSC(2020): 51E20,51E22

The Embedding of the Ree-Tits Octagon

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Joint work with: Hendrik Van Maldeghem

Abstract

In this talk, we study and characterise the natural embedding of the Ree-Tits octagons. Generalised polygons are fundamental in incidence geometry and building theory. A thick generalised n-gon can be defined as a point-line geometry with at least three points on every line and at least three lines through every point such that the incidence graph has diameter n and girth $2n$. Up to duality, only one class of generalised octagons is known: the Ree-Tits octagons. They are defined as substructures of metasymplectic spaces. We show that any generalised octagon embedded in a metasymplectic space satisfies some simple conditions if, and only if, it is a Ree-Tits octagon. This continues previous work by Rijpert and Van Maldeghem [1]. Along the way, we introduce the concepts of pseudo-isometric and ovoidal and show how these properties are linked together.

Keywords: Ree-Tits Octagon; Metasymplectic space; Generalised Octagon

MSC(2020): 51E12, 51E24

References

[1] D. Rijpert and H. Van Maldeghem. "*Weyl substructures of spherical buildings*". submitted manuscript.

MSC(2020): 51E30, 20D20, 51E24

p-Sylow geometries of Classical groups

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Joint work with: João Dias

Abstract

p-Sylow subgroups play a central role in understanding the structure of finite groups. Despite their importance, geometric structures admitting p-Sylow subgroups of classical groups as automorphism groups have not been systematically explored until recently.

In this talk, we introduce a family of incidence structures for the upper unitriangular group $UT(n, q)$, the p-Sylow subgroups of $GL(n, q)$, with $q = p^m$. These structures are constructed as coset geometries, i.e. incidence structures arising from a group together with a chosen family of its subgroups.

Additionally, we will explore also structures for particular subgroups of $UT(n, q)$, namely Pattern groups. In fact, due to the one-to-one correspondence of these groups to a poset on $\{1, \ldots, n\}$, one can translate properties of this poset into properties of its coset geometry.

Finally, we show early results of p-Sylow geometries for other groups such as the Symmetric group and the Alternating group of degree p^m.

Keywords: Incidence structures; Coset geometry; Unitriangular group; Pattern group

Edge-connectivity of vertex-transitive hypergraphs

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Joint work with: Andrea C. Burgess and Robert D. Luther

Abstract

A graph or hypergraph is said to be vertex-transitive if its automorphism group acts transitively upon its vertices. A classic theorem of Mader asserts that every connected vertex-transitive graph is maximally edge-connected. We generalise this result to hypergraphs and show that every connected linear uniform vertex-transitive hypergraph is maximally edge-connected. By using combinatorial designs, we also show that if we relax either the linear or uniform conditions in this generalisation, then we can construct examples of vertex-transitive hypergraphs which are not maximally edge-connected.

Keywords: connectivity, hypergraphs, vertex-transitivity

References

[1] A.C. Burgess, R.D. Luther and D.A. Pike. "*The edge-connectivity of vertex-transitive hypergraphs*", J. Graph Theory, **105**:252–259, 2024.

MSC(2020): 05C40, 05E18, 05C65

Partial cubes and resonance graphs

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Joint work with: Tomislav Došlić

Abstract

We present a two-parameter family of graphs that further generalizes the Fibonacci cubes. The number of vertices in this family of graphs is counted by the sequence with recurrence $s_n = as_{n-1} + s_{n-2}$, a linear recurrence of order two. We show that many appealing and useful properties of the Fibonacci cubes are preserved. Furthermore, we present metallic cubes as resonance graphs of a special family of benzenoids. Finally, we further extend this family by considering graphs whose vertices satisfy Horadam's recurrence $s_n = as_{n-1} + bs_{n-2}$.

Keywords: linear recurence; Fibonacci sequence; Horadam sequence; resonance graph.

MSC(2020): 05C30, 05C92

The enumeration of some finite quotients of surface braid groups, and complex surfaces of general type

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Joint work with: Massimiliano Alessandro and Michelangelo Migliano

Abstract

Let Σ_g be a compact Riemann surface of genus $g \geq 2$, and let $\mathrm{B}_2(\Sigma_g)$ denote the Artin braid group on two strands over Σ_g. We obtain closed formulas for the number of finite abelian and dihedral quotients

$$\varphi \colon \mathrm{B}_2(\Sigma_g) \to G$$

that do not factor through $\pi_1(\mathrm{Sym}^2 \Sigma_g)$. We further prove the existence of additional extra-special quotients, including finite Heisenberg quotients.

As an application, we describe a related construction of complex surfaces of general type arising from these quotient structures. Our results extend to the Artin braid group setting results previously obtained for pure braid groups, see [1, 2].

The proofs combine methods from combinatorial group theory with explicit computations carried out in the computer algebra system `GAP4`.

Keywords: Surface braid groups, finite groups, complex surfaces

References

[1] A. Causin, F. Polizzi. "*Surface braid groups, finite Heisenberg covers and double Kodaira fibrations*", Ann. Sc. Norm. Super. Pisa Cl. Sci., XXII: 1309-1352, 2021.

[2] F. Polizzi, P. Sabatino. "*Extra-special quotients of surface braid groups and double Kodaira fibrations with small signature*", Geom. Dedicata, 216: 65, 2022.

MSC(2020): 20F36, 20D15, 05E16, 14J29

MSC(2020): 05C51,05C15,05B30

Uniquely 2-colourable 4-cycle systems exist!
A blossoming construction

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Joint work with: Andrea C. Burgess and David A. Pike

Abstract

A cycle system of order n is a decomposition of the edges of the complete graph K_n into cycles of a fixed length. A cycle system is said to be k-colourable if we can assign k colours to its vertices so that no cycle is monochromatic. If a cycle system is k-colourable but not $(k-1)$-colourable, it is called k-chromatic. A k-colourable cycle system is uniquely k-colourable if its colouring is unique up to the permutation of colour classes.

The study of colouring cycle systems has been explored in various settings. In particular, Horsley and Pike have examined the existence of k-chromatic m-cycle systems for any integers $m > 2$ and $k > 1$. While Forbes has investigated 3-cycle systems with unique 3-colourability, the existence of uniquely k-colourable m-cycle systems in general remains an open problem.

In this talk, we mainly focus on the construction of an infinite family of uniquely 2-colourable 4-cycle systems and also a uniquely 2-colourable 4-cycle decomposition of $K_n - I$, for infinitely many integers $n \geq 2$. These constructions contribute to the broader study of uniquely colourable cycle systems and open new directions for future research.

Keywords: cycle systems, graph coloring, unique coloring, combinatorial design

$PGL_2(q)$-orbits of lines of $PG(3,q)$ and binary quartic forms in characteristic three

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Joint work with: Krishna Kaipa

Abstract

Let $PG(3,q)$ denote the 3-dimensional projective space defined over a finite field $\mathbb{F}_q$. The lines of $PG(3,q)$ are the one dimensional subspaces of $PG(3,q)$. Let C be the twisted cubic in $PG(3,q)$ defined by the image of the embedding

$$PG(1,q) \hookrightarrow PG(3,q), \quad (s,t) \mapsto (s^3, s^2t, st^2, t^3).$$

The twisted cubic is left invariant under the action of a group $G \leq PGL_4(q)$, which is isomorphic to $PGL_2(q)$ if $q > 4$. The standard action of $PGL_2(q)$ on the points of $PG(1,q)$, induces an action on the points of C, and this action extends to an action of $PGL_2(q)$ on $PG(3,q)$. A binary quartic form over $\mathbb{F}_q$ is a homogeneous polynomial of degree 4 in variables X, Y, whose coefficients are in $\mathbb{F}_q$. The group $PGL_2(q)$ acts on binary quartic forms by $(g \cdot f)(X,Y) = f(dX - bY, aY - cX)$, where $g = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$ and $ad - bc \neq 0$.

In this talk, we shall first discuss about the $PGL_2(q)$-orbits classification of the binary quartic forms over $\mathbb{F}_q$, when char($\mathbb{F}_q$)$= 3$. Then we shall discuss how to use these results to obtain the $PGL_2(q)$-orbits classification of the lines of $PG(3,q)$. This is a joint work with Krishna Kaipa.

Keywords: Relevant Keywords; for the paper; etc.

MSC(2020): 00X01, 01X02

References

[1] K. Kaipa, P. Pradhan. "*On the $PGL_2(q)$-orbits of lines of $PG(3,q)$ and binary quartic forms in characteristic three*", Finite Fields Appl., **111**:40pp., 2026.

Triangle-free subsets of the r-distance graph of the Hypercube

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Joint work with: Padmini Mukkamala

MSC(2020): 05D05, 05C35

Given the r-distance graph on the hypercube $\mathbb{F}_2^n$, where two vertices are adjacent if their Hamming distance is exactly r, we study the maximum size $T(n,r)$ of a triangle-free set of vertices. For even $r \leq n/2$, we prove

$$T(n,r) = O\left(\frac{r2^n}{n+1}\right).$$

We also obtain lower bounds in various regimes of r as a function of n.

arXiv:2506.18782

References

[1] D. Castro-Silva, F. M. de Oliveira Filho, L. Slot, and F. Vallentin, A recursive theta body for hypergraphs, *Combinatorica* **43** (2023), 909–938.

Graphs of quadratic forms generated by vector spaces over finite fields

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Joint work with: Jean Godard (UFMG)

Abstract

Motivated by the well known Paley-Graphs over finite fields, in a recent work [1] we considered an additive-multiplicative analogue. Namely, for each $\mathbb{F}_q$-vector subspace V of the finite field $\mathbb{F}_{q^n}$, $\Gamma(XY, V)$ is the graph with vertex set $\mathbb{F}_{q^n}$ and edges (a, b) if $ab \in V$. We provided many results towards the structure of this graph, and also bounds for its clique number. In particular, we computed the clique number when V has dimension $1, 2$ or $n - 1$.

In this talk we discuss a generalization of this work, replacing the polynomial XY by a generic quadratic form $P(x, y) = AX^2 + BXY + CY^2 \in \mathbb{F}_{q^n}[X, Y]$ with $(A, B, C) \neq (0, 0, 0)$. In this new setting the corresponding graph is, in general, directed and we completely describe the forms P for which this graph remains undirected for every possible V. For these quadratic forms, we study classical issues on the corresponding graphs such as clique number, connectivity, girth and circumference.

This talk is based on a joint work with Jean Godard (in final preparation).

Keywords: finite fields; quadratic forms; vector spaces; character sums.

MSC(2020): 12E20, 11T24, 05D05

References

[1] L. Reis. "*Paley-like graphs over finite fields from vector spaces*", Finite Fields and Their Applications, **88**:102171, 2023.

On projection cubes of symmetric designs

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Joint work with: V. Krčadinac and M. O. Pavčević

Abstract

Projection cubes of symmetric designs are n-dimensional matrices of zeros and ones such that every 2-dimensional projection is an incidence matrix of a (v, k, λ) design. We will present a 3D-printed model of the 3-dimensional $(7, 3, 1)$ projection cube as an example. Moreover, we will discuss some basic properties and constructions of projection cubes from [1] and [2]. There is an upper bound on the dimension, $n \leq (vk - 1)/(k - 1)$, and examples can be obtained from suitably defined higher-dimensional difference sets. A sharper upper bound $n \leq v$ holds for projection cubes constructed in this way. Projection cubes arise as a special case of n-dimensional symmetric (v, k, λ) designs of propriety d, studied in [3].

Keywords: higher-dimensional design; symmetric design; difference set

MSC(2020): 05B05, 05B10, 05B20

References

[1] V. Krčadinac, L. Relić. "*Projection cubes of symmetric designs*", Math. Comput. Sci., 2013. `https://arxiv.org/abs/2411.06936`

[2] V. Krčadinac, M. O. Pavčević. "*On higher-dimensional symmetric designs*", Exp. Math., 2025. `https://arxiv.org/abs/2412.09067`

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Rank two commutative semifields

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Joint work with: Michel Lavrauw

Abstract

Finite semifields are finite division algebras that are not assumed to be associative. Commutative semifields in particular have been extensively studied due to their connections to perfect nonlinear functions. Classifying the rank two commutative semifields having dimension $2n$ over centre $\mathbb{F}_q$ amounts to classifying linear sets in $\mathrm{PG}(2, q^n)$ which are contained in the interior points of a conic C. This interpretation allows bounds to be given on q in terms of n, see [1]. While classifications for dimensions 2, 4, and 6 are known, this is in general a very difficult computational problem. The 8-dimensional examples were classified in [2], along with the 10-dimensional examples over $\mathbb{F}_3$; it is conjectured that any further examples must have center $\mathbb{F}_3$. We outline a technique that can be used to approach this problem based on a method for classifying double coset representatives. We will demonstrate these techniques by re-proving the classification of 10-dimensional rank two commutative semifields over $\mathbb{F}_3$, and extending to those of dimension 12; we will also discuss some difficulties that arise in extending this to the 14-dimensional case, as well as to examples with larger fields as their centre.

Keywords: Commutative semifields, linear sets

MSC(2020): 51E20, 12K10

References

[1] Lavrauw, M. "*Sublines of prime order contained in the set of internal points of a conic*", Designs, Codes and Cryptography, **38**(1):113–123, 2006.

[2] Lavrauw, M., Rodgers, M. "*Classification of 8-dimensional rank two commutative semifields*", Advances in Geometry, **19**(1):57–64, 2019.

MSC(2020): 20B25, 05B05, 05B25

A classification of the flag-transitive 2-(v, k, λ) designs with $\lambda \geq (r, \lambda)^2$

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Joint work with: Mario Galici and Alessandro Montinaro

Abstract

The 2-designs $\mathcal{D} = (\mathcal{P}, \mathcal{B})$ possessing a high degree of symmetry are of great interest, in particular those admitting a flag-transitive automorphism group G. If $\lambda = 1$ then G is point-primitive, and a satisfactory classification of the pairs $(\mathcal{D}, G)$ was obtained by Liebeck et al. (1990). If $\lambda > 1$, it is well known that the aforementioned conclusions are no longer true, and important results were obtained by O'Reilly-Regueiro (2006) and Praeger et al. for $\lambda \leq 4$ (2009), and by Mandić and Šubasić for $\lambda \leq 10$ (2022). However, in his famous book *Finite Geometries*, Dembowski provided some remarkable conditions on the parameters of $\mathcal{D}$ that ensure point-primitivity, such as $\lambda \geq (r, \lambda)^2$. Further, under this assumption, Zhan and Zhou have recently proved that either G is of affine type or of almost simple type.

The aim of this talk is to provide an approach to classify the pairs $(\mathcal{D}, G)$ when $\lambda \geq (r, \lambda)^2$ and G is of affine type. In this context, the point-set of $\mathcal{D}$ can be endowed with the structure of a d-dimensional vector space V over $GF(p)$ so that $G = T : G_0$, where T is the translation group of V, $G_0 \leq GL_d(p)$ and 0 denotes the zero-vector of V. In my talk, I will show how we used the Aschbacher's Theorem and an analysis of the underlying geometry of G_0 to determine the admissible pairs $(\mathcal{D}, G)$.

Keywords: 2-designs; flag-transitive designs; primitive permutation groups

MSC(2020): 51E20, 51E21

On (q^2+q, q)-blocking sets in PG$(2, q)$

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Joint work with: Ivan Landjev

Abstract

In [1] a class of arcs $\mathcal{K}$ with parameters $(q^2+q+2, q+2)$ in PG$(2, q)$ was investigated. The maximal point multiplicity in such arcs is 2 and the multiset $\mathcal{F} = 2 - \mathcal{K}$ is a $(q(q+1), q)$-blocking set. Blocking sets with these parameters can be considered without the restriction on the maximal point multiplicity. This relaxation gives new constructions that differ from those described in [1]. For instance, for $\lambda_0 = 6$ (six 0-points) we have the following:

- blocking sets with collinear 0-points;
- blocking sets in which the 0-points are on two lines (three 0-points on each of the lines) for the cases $q \equiv 1 \pmod 6$ and $q = 2^h$, h - even;
- blocking sets in which no three 0-points are collinear for $q = 2^h$, h -even.

In [1] just the first type was described. In this talk we focus on $(q(q+1), q)$-blocking sets in PG$(2, q)$ with a small number of 0-points. We present several constructions and give a complete classification for small prime fields, i.e. fields of order $p \leq 11$.

Keywords: arcs; blocking sets; maximal arcs

References

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Finite quotients of pure surface braid groups and double Kodaira surfaces

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Joint work with: Francesco Polizzi

Abstract

Let Σ_b be a compact Riemann surface of genus b for $b \geq 2$. Define $\mathsf{P}_2(\Sigma_b)$ as the pure braid group on two strands on Σ_b, which is the fundamental group $\pi_1(\Sigma_b \times \Sigma_b - \Delta)$ where Δ is the diagonal in $\Sigma_b \times \Sigma_b$. Let A_{12} represent the homotopy class of a geometric braid that loops once around the diagonal. A surjective homomorphism $\varphi \colon \mathsf{P}_2(\Sigma_b) \to G$ onto a finite group G is called *admissible* if $\varphi(A_{12})$ has order $n \geq 2$, and the finite group G an *admissible braid quotient* of type $(b,\, n)$. Following our recent work, see [1], we highlight the significance of admissible quotients of $\mathsf{P}_2(\Sigma_b)$ in algebraic geometry, particularly in constructing double Kodaira surfaces, which are special complex algebraic surfaces of general type. We also illustrate the results from [2], which provide a complete classification of admissible quotients with $|G| \leq 127$ for every genus $b \geq 2$. The techniques employed blend combinatorial group theory with explicit computations using the computer algebra system `GAP4`.

Keywords: Surface braid groups, finite groups, complex surfaces

MSC(2020): 20F36, 20D15, 05E16, 14J29

References

[1] F. Polizzi, P. Sabatino. "*Groups of order 64 and non-homeomorphic double Kodaira fibrations with the same biregular invariants*", arXiv:math.AG, `https://arxiv.org/abs/2412.08260`, 2025.

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Designs, toric ideals, and three-point functions

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Joint work with: Barbara Betti, Sean Grate, and Thiago Holleben

Abstract

Consider n massless particles represented by momentum vectors $p_1, \ldots, p_n$ in $\mathbb{C}^d$ and denote by $p_{i,j}$ the pairwise products $p_i \cdot p_j$ with respect to the Lorentzian inner product. In Conformal Field Theory, correlators, also known as n-point functions, play the role of "observables". These are functions describing the correlation between quantum field operators located at n points in the spacetime. The general form of 2- and 3-point functions is determined by the conformal symmetry up to a finite number of parameters. Higher-point functions are more complex, but in many cases we can reduce them to 2- and 3-point functions through the operator product expansion (OPE). Here we focus on the following simplified form of three-point functions

$$c_{i,j,k} := \frac{1}{p_{i,j}p_{j,k}p_{i,k}}.$$

We are interested in studying the algebraic relations among the 3-point functions. In particular, when $n \leq d$, we obtain a toric ideal I. In this talk, we will show that 3-uniform null 2-designs provide a generating set for this toric ideal I. We then generalize this approach to a larger class of ideals that we call incidence toric ideals. Finally, we will show that considering only the elements of the ideal corresponding to octahedral designs (also known as $(2,3)$-pods) is sufficient to capture many of the parameters of the ideal.

We note that although the initial motivation stems from a physical context, the nature of the problem addressed is purely combinatorial, and the techniques used belong primarily to design theory.

Keywords: Null design, toric ideal, 3-point function, octahedra.

MSC(2020): 05B05, 05E45

MSC(2020): 05E05, 94B05, 11G20

Linear system of curves and evaluation codes

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Joint work with: B. Gatti, G. Korchmáros

Abstract

In [1] Datta and Johnsen introduced a new family of evaluation codes where linear combinations of elementary symmetric polynomials are evaluated on the set of all points with pairwise distinct coordinates in the affine space of dimension ≥ 2 over a finite field $\mathbb{F}_q$. A generalization arises from m-dimensional linear systems of symmetric polynomials. The odd characteristic case was studied in [2]. In this talk we consider the even characteristic, and work out thoroughly the case $m = 2$.

Our main result is the following.

Theorem 1. *The Datta-Johnsen code arising from the linear system of all conics is* $\left[\frac{1}{2}q(q-1), 6, \frac{1}{2}q(q-3)\right]_q$.

Keywords: evaluation code; symmetric polynomials; finite field

References

[1] M. Datta, T. Johnsen. "*Codes from symmetric polynomials*", Des. Codes and Cryptogr., **91**: 747–761, 2023.

[2] B. Gatti, G. Korchmáros, G. P. Nagy, V. Pallozzi Lavorante, G. Schulte. "*Evaluation codes arising from symmetric polynomials*", Des. Codes and Cryptogr., **93**: 3361–3373, 2025.

(s, t)-intersecting codes

Martin Scotti
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Joint work with: Martino Borello & Chiara Castello

Abstract

In this talk, we introduce (s, t)-intersecting codes, which are Hamming-metric codes such that for any s linearly independent codewords $c_1, \ldots, c_s$, there exist t such that their support intersect nontrivially:

$$\sigma(c_1) \cap \cdots \cap \sigma(c_t) \neq \varnothing.$$

This generalizes both the classical notion of intersecting codes (which correspond to the special case $s = t = 2$, studied recently in [2]), which have many applications to other areas of mathematics, and t-wise intersecting codes (which correspond to the case $s = t$, studied for instance in [1]).

We propose a geometric interpretation of such codes, and provide bounds on their parameters as well as some constructions.

Keywords: Intersecting codes

References

[1] Gérard Cohen, Gilles Zémor. "*Intersecting codes and independent families*", IEEE TRANSACTIONS ON INFORMATION THEORY, **40**(6):1872–1881, 1994.

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MSC(2020): 94B05, 94B65, 94B27

Metric dimension and fault tolerance

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Joint work with: Martin Knor and Riste Škrekovski

Abstract

A resolving set S distinguishes every pair of vertices in G by their distance to at least one vertex in S. The metric dimension $\dim(G)$ is the size of the smallest resolving set. The fault-tolerant metric dimension $\text{ftdim}(G)$ is the size of the smallest resolving set that remains resolving even after removing any one vertex. It is known that

$$\text{ftdim}(G) \leq \dim(G)\big(1 + 2 \cdot 5^{\dim(G)-1}\big),$$

which grows exponentially with $\dim(G)$, but no graph was previously known in which $\text{ftdim}(G)$ is actually exponential in $\dim(G)$. We construct graphs where

$$\text{ftdim}(G) = \dim(G) + 2^{\dim(G)-1}$$

for every positive integer value of $\dim(G)$. This proves that the exponential upper bound is necessary. We extend the result to the k-metric dimension $\dim_k(G)$, which is a natural generalization of the fault-tolerant metric dimension. First we prove a similar exponential upper bound on $\dim_{k+1}(G)$ in terms of $\dim_k(G)$. Then we construct graphs showing that the bound must indeed be exponential. An important open problem is to narrow the gap between the existing upper and lower bounds for both the fault-tolerant metric dimension and the more general k-metric dimension.

Keywords: Metric dimension; Fault-tolerant metric dimension, k-metric dimension.

MSC(2020): 05C12

On Kotzig's conjecture in random graphs

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Joint work with: Stefan Glock

Abstract

In 1963, Anton Kotzig famously conjectured that K_n, the complete graph of order n, where n is even, can be decomposed into $n-1$ perfect matchings such that every pair of these matchings forms a Hamilton cycle. The problem is still wide open and here we consider a variant of it for the binomial random graph $G(n,p)$. In fact, our main result is a very precise answer for the following counting problem: given any k edge-disjoint perfect matchings $M_1, \ldots, M_k$ of K_n, how many perfect matchings M^* in K_n have the property that $M_i \cup M^*$ forms a Hamilton cycle for each $i \in [k]$?

Keywords: Kotzig's conjecture, perfect 1-factorisation

MSC(2020): 05C70, 05D40

MSC(2020): 05B20,15B36,05B15,15B48

Generalisations of Latin Squares

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Joint work with: Alena Ernst, Stefano Lia, Cian O'Brien, Jens Zumbrägel

Abstract

Alternating Sign Matrices (ASMs) are generalisations of permutation matrices which arise naturally in various combinatorial contexts. A three-dimensional analogue, *Alternating Sign Hypermatrices (ASHMs)*, was introduced in [1], with an associated proposed generalisation of a Latin Square called *Latin-like Squares*. These were further explored in [2], with an alternative generalisation proposed which appears more suitable for considerations of orthogonality.

Definition 1. An *Alternating Sign Hypermatrix* is an $n \times n \times n$ array with entries from $\{0, \pm 1\}$ such that, fixing any two indices and increasing the third, the non-zero entries alternate in sign, beginning and ending with $+1$.

In this work we study natural generalisations of various concepts from Latin Squares; for example transversals, and sets of mutually orthogonal elements. We answer various open problems from [1], giving results on the existence of orthogonal mates to ASMs, the existence of orthogonal proper ASHMs, and the maximum size of a set of mutually orthogonal ASHMs.

Keywords: Latin Square, orthogonality, alternating sign matrices.

References

[1] R. A. Brualdi and G. Dahl, "*Alternating sign matrices and hypermatrices, and a generalization of Latin squares.*", Adv. in Appl. Math., **95**(1):116–151, 2018.

[2] C. O'Brien, "*Alternating sign hypermatrix decompositions of Latin-like squares.*", Adv. in Appl. Math., **121**(1):102097, 2020.

Thirty-six quantum officers are entangled

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Joint work with: Simeon Ball

Abstract

Euler's thirty-six officers problem asks whether six army regiments, each with six officers of different ranks, can be arranged in a 6×6 square such that no row or column repeats a rank or regiment. It took more than a century to prove that such a configuration is impossible, or equivalently, that a pair of orthogonal Latin squares of order six does not exist [3].

Surprisingly, a solution *does* exist for a recent quantum version of the problem, where officers can have an entangled mixture of ranks and regiments [2]. This raises a question: is entanglement truly necessary, or is there an "in-between" solution of *orthogonal quantum Latin squares* without entanglement?

In this talk, I will show that entanglement is indeed essential, resolving the last open case on the existence of (non-entangled) orthogonal quantum Latin squares. This talk is based on the results in [1].

Keywords: Quantum Latin square; Orthogonal quantum Latin squares.

MSC(2020): 05B15, 05C62, 81P70

References

[1] S. Ball, R. Simoens. "*Thirty-six quantum officers are entangled*", arXiv preprint, arXiv:2603.02334, 2026.

[2] S.A. Rather, A. Burchardt, W. Bruzda, G. Rajchel-Mieldzioć, A. Lakshminarayan, K. Życzkowski. "*Thirty-six Entangled Officers of Euler: Quantum Solution to a Classically Impossible Problem*", Phys. Rev. Lett., **128**(8):080507, 2022.

[3] G. Tarry. "*Le problème des 36 officiers*", Comptes Rendus Assoc. France Av. Sci., **29**(2):170–203, 1900.

List proper conflict-free colorings

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Joint work with: Rongxing Xu and Masaki Kashima

Abstract

A proper vertex coloring φ of a graph G is said to be *conflict-free* if, for each non-isolated vertex $x \in V(G)$, there exists a color c such that $\varphi^{-1}(c) \cap N(x)$ has size one. In other words, in the neighborhood of every non-isolated vertex, some color appears exactly once.

In this talk, I will introduce a list version of this coloring and present some recent results and questions concerning the degree-choosability of conflict-free colorings of planar graphs, obtained jointly with Rongxing Xu (China) and Masaki Kashima (Japan).

Keywords: Keywords: graph; vertex coloring; conflict-free coloring; list coloring

MSC(2020): 05C15, 05C10

Switching in tangent polar graphs

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Abstract

Finite classical polar spaces are incidence structures arising from isotropic subspaces w.r.t. non-degenerate reflexive sesquilinear forms. We distinguish between quadrics (of elliptic, parabolic or hyperbolic type), symplectic spaces and Hermitian varieties.

The tangent polar graph can then be introduced as follows: the set of non-isotropic points forms the vertex-set, and two points represent adjacent vertices if and only if they lie on a line tangent to the polar space.

The graphs $NU(n+1,q^2)$ and $NO^{\varepsilon}(n,2)$ $(\varepsilon = 0, 1, -1)$ are well known to be strongly regular, and the polar space in question is either a Hermitian variety or a quadric over a binary field. In this talk, we will provide an overview of old and recent results on this family of graphs and their switching equivalences.

Keywords: polar spaces; strongly regular graphs

References

[1] A. E. Brouwer, H. Van Maldeghem. “*Strongly Regular Graphs*”, Encyclopedia of Mathematics and its Applications, Cambridge University Press, 2022.

MSC(2020): 51E20, 05E30

Dense induced subgraphs of the hypercube

Victor Souza

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Joint work with: Harry Metrebian

Abstract

In his solution to the sensitivity conjecture, Huang [2] has shown that every subset S consisting of at least $2^{n-1}+1$ vertices of the n-dimension hypercube contains a vertex with at least $\sqrt{n}$ neighbours in S, matching exactly a construction of Chung, Füredi, Graham, and Seymour [1]. We further the program initiated by Huang by asymptotically determining the minimum value of the max-degree of an subgraph of the hypercube induced by $p2^n$ vertices for infinitely many fixed values of $p > 1/2$. We show that this extremal parameter has points of non-analicity, with an emerging picture that resembles the Razborov's[3] edge-triangle density diagram. Our constructions involve randomised blow-ups of equitable partitions of the hypercube. Lower bounds are obtained analytically from a careful considerations of the local densities of small configurations.

Keywords: Induced subgraphs of hypercube; Equitable partitions; Hamming Codes

MSC(2020): 05DXX, 94BXX

References

[1] Fan Chung, Zoltán Füredi, Ronald Graham, and Paul Seymour. "*On induced subgraphs of the cube*", Journal of Combinatorial Theory, Series A, **49**(1):180–187, 1988.

[2] Hao Huang. "*Induced subgraphs of hypercubes and a proof of the Sensitivity Conjecture*", Annals of Mathematics, **190**(3):949–955, 2019.

[3] Alexander Razborov. "*On the minimal density of triangles in graphs*", Combinatorics, Probablity, and Computing, **17**(4):603–618, 2008.

On the complement of a signed graph

Stefano Spessato

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Joint work with: M. Cavaleri and A. Donno

Abstract

Given a graph Γ, its *complement* Γ^c is the graph with the same vertex set of Γ and whose edges are precisely those not present in Γ. The properties of the graph complement have been widely studied and have led to several important results in spectral graph theory. In last decades, much attention has been devoted to *signed graphs*, that is, graphs whose edges carry a positive or negative sign. This naturally raises the problem of defining signed analogues of classical graph operations. While many constructions admit natural signed versions, the notion of complement for signed graphs has turned out to be more subtle and appeared among the open problems in the spectral theory of signed graphs [1]. In this talk I will present a solution given in the 2025 paper [2] by M. Cavaleri, A. Donno, and myself. This solution satisfies the expected geometric and spectral properties and coincides with the classical complement when applied to all-positive graphs.

Keywords: Signed graph, Complement graph, Spectral graph theory

MSC(2020): 05C22, 05C76

References

[1] F. Belardo, S.M. Cioabă, J. Koolen, J. Wang, "*Open problems in the spectral theory of signed graphs*", Art Discrete Appl. Math. **1**(2), 2018.

[2] M: Cavaleri, A. Donno, S. Spessato. "*On the complement of a signed graph*", Discrete Mathematics **348**(6), 2025.

Non-Additive Partition Codes in the Sum-Rank Metric

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University Paris Cité (France)
Télécom Paris (France)
Joint work with: Ferdinando Zullo

Abstract

The sum-rank metric has emerged as a unifying framework for Hamming and rank metrics, combining features of both classical block codes and rank-metric codes. In this work, we generalize the non-additive partition codes introduced by Otal and Özbudak [1] to the framework of the sum-rank metric. We construct a new family of nonlinear codes and prove that they are not equivalent to linear codes. We further show that this family attains the Singleton-type bound for the sum-rank metric, and hence consists of MSRD codes, the natural analogue of MDS codes in the Hamming metric. As a consequence, we obtain what appears to be the first explicit construction of nonlinear MSRD codes. Finally, we provide a decoding algorithm for the proposed family.

Keywords: Sum-Rank Metric; Maximum Sum-Rank metric codes; Decoding algorithm

MSC(2020): 94B60, 94B35, 11T71

References

[1] K. Otal, F. Özbudak. "*Some new non-additive maximum rank distance codes*", Finite Fields and Their Applications, **50**:293–303, 2018.

Spherical Codes in Buildings

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Abstract

Via the language of Bruhat-Tits buildings we can interpret a particular class of submodule codes over finite commutative chain rings as spherical codes in an infinite simplicial complex. Within this context we introduce a new class of Sperner codes and show how results from extremal combinatorics yield the optimality of such codes in different cases. We also present a number of open questions.

Keywords: Submodule codes, subspace codes, spherical codes, chain rings, Sperner property, Bruhat–Tits buildings.

References

[1] Mima Stanojkovski. "*Submodule codes as spherical codes in buildings*", Des. Codes Cryptogr. **91**, 2449–2472, 2023.

MSC(2020): 94B60, 94B65, 94B25, 20E42, 51E24, 52B20

On rainbow caterpillars

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Joint work with: S. Cichacz, M.Woźniak

Abstract

Given a finite Abelian group $(A,+)$, consider a tree T with $|A|$ vertices. The labeling $f\colon V(T) \to A$ of the vertices of some graph G induces an edge labeling in G, thus the edge uv receives the label $f(u)+f(v)$. The tree T is A-rainbow colored if f is a bijection and edges have different colors. In this paper, we give necessary and sufficient conditions for a caterpillar with three spine vertices to be A-rainbow, when A is an elementary p-group.

Keywords: Rainbow Labeling, group labeling

MSC(2020): 05C78

Partial t-spreads and minimal t-covers in finite classical polar spaces

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Joint work with: Sascha Kurz and Laure Schelfhout

Abstract

A t*-spread* $\mathcal{S}$ of a finite classical polar space $\mathcal{P}$ is a set of t-spaces of this polar space $\mathcal{P}$, partitioning the point set of $\mathcal{P}$. A *partial* t*-spread* $\mathcal{S}$ of a finite classical polar space $\mathcal{P}$ is a set of pairwise disjoint t-spaces of $\mathcal{P}$. A *maximal* partial t-spread $\mathcal{S}$ of $\mathcal{P}$ is a partial t-spread of $\mathcal{P}$, which is not properly contained in a larger partial t-spread of $\mathcal{P}$.

A t*-cover* $\mathcal{C}$ of a finite classical polar space $\mathcal{P}$ is a set of t-spaces of this polar space $\mathcal{P}$, such that every point of $\mathcal{P}$ belongs to at least one t-space of $\mathcal{C}$. A t-cover $\mathcal{C}$ of a finite classical polar space $\mathcal{P}$ is *minimal* when no proper subset of $\mathcal{C}$ still is a t-cover of $\mathcal{P}$.

For $(t+1)|n$, we present constructions of partial t-spreads of the parabolic quadric $Q(2n+2,q)$, q even. When $t > q$, the constructed partial t-spreads of $Q(2n+2,q)$, q even, are of the largest possible size.

We also investigate the largest possible size for partial t-spreads of the hyperbolic quadrics $Q^+(2n+1,q)$, under the condition $(t+1)|n$.

Furthermore, (1) t-covers of $Q^+(2n+1,q)$, q even, $(t+1)|n$, of minimum size were constructed, and (2) minimal $2n$-covers of $Q^+(4n+1,q)$, q even, were investigated.

Keywords: Partial t-spread; Minimal t-cover; Finite classical polar space

MSC(2020): 51E20,51E23

References

[1] L. Schelfhout, *Substructures of Finite Projective Spaces and Finite Classical Polar Spaces*. Master thesis Ghent University, Academic Year 2024-2025.

On some new directed strongly regular graphs having 60 vertices

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Joint work with: Dean Crnković and Matea Zubović Žutolija

Abstract

In this talk, we describe a construction of certain regular digraphs using finite simple groups. We prove the existence of some directed strongly regular graphs having 60 vertices, and admitting S_5 as an automorphism group. Further, we introduce the notion of orbit matrices of digraphs.

Keywords: directed strongly regular graph; transitive group; symmetric group.

MSC(2020): 05C20, 05B20, 05E30.

Combinatorial transfer: a method for constructing infinite families of difference sets and partial difference sets in nonabelian groups

Eric Swartz

William & Mary (USA)

Joint work with: James A. Davis, John Polhill, and Ken W. Smith

Abstract

For nearly a century, mathematicians have been developing techniques for constructing abelian automorphism groups of combinatorial objects, and, conversely, constructing combinatorial objects from abelian groups. While abelian groups are a natural place to start, recent computational evidence strongly indicates that the vast majority of transitive automorphism groups of combinatorial objects are nonabelian. With this motivation in mind, we propose a new method for constructing nonabelian automorphism groups of combinatorial objects, which could be called the *combinatorial transfer method*, and we demonstrate its power by constructing several new infinite families of difference sets and partial difference sets in nonabelian groups, including (1) the first infinite families of nonabelian Denniston partial difference sets (including nonabelian Denniston PDSs of odd order), (2) the first infinite family of Spence difference sets in groups with a Sylow 3-subgroup that is non-normal and not elementary abelian, and (3) the first infinite families of McFarland difference sets in groups with a Sylow p-subgroup that is non-normal and is not elementary abelian.

Keywords: difference set, partial difference set

MSC(2020): 05B10

The general position no-$(d+2)$-on-a-sphere problem and its generalisations

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Abstract

The *general position no-$(d+2)$-on-a-sphere problem* (originating from Erdős and Purdy) asks for $f_d(n)$, the size of the largest $\Gamma \subseteq \{1, \ldots, n\}^d$ in general position such that no hypersphere in $\mathbb{R}^d$ contains $d+2$ points of Γ. Trivially $f_d(n) \leq dn$. The next result improves the previously known lower bounds, namely $\frac{3}{32}n^{1/(d-1)} \leq f_d(n)$ due to [3], and the $\frac{1}{d+1}n - o(n) \leq f_d(n)$ due to [2].

Theorem 1 ([1]). *For every $d \geq 2$, we have $n - o(n) \leq f_d(n)$ as $n \to \infty$.*

More generally, we prove that the role of hyperspheres above can be replaced by Q-quadrics, i.e. by quadratic hypersurfaces given by a polynomial whose degree 2 homogeneous part equals any fixed quadratic form $Q \neq 0$. We formulate analogous statements in vector spaces over finite fields.

All of these constructions emerge from carefully chosen rational normal curves in finite projective spaces obtained by generalising the ideas of [2, 3].

Keywords: Erdős–Purdy problem; rational normal curve; quadratic form

MSC(2020): 52C35, 52C10, 05D40

References

[1] Dávid R. Szabó. "*Rational normal curves as no-$(d+2)$-on-Q-quadric sets*", arXiv:2511.03526, 2025.

[2] Zichao Dong, Zijian Xu. "*Large grid subsets without many cospherical points*", arXiv:2506.18113, 2025.

[3] Torsten Thiele. "*The no-four-on-circle problem*", Journal of Combinatorial Theory, **71**(2):332–334, 1995.

Large line-free sets and their applications

Vladislav Taranchuk

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Joint work with: Jakob Führer

Abstract

In this talk, we will present our recent construction of t-line evasive sets which are significantly larger than those previously known.

Definition 1. Let q and be a prime power and n a positive integer. A subset $S \subset \mathbb{F}_q^n$ is called t-line evasive set if each affine line intersects S in at most t points.

For each prime power q and integer $2 \leq t \leq q-1$, we construct t-line evasive subsets of $\mathbb{F}_q^n$ of size

$$q^{n\left(1-\frac{2}{t^2+t}\right)}.$$

Moreover, our method yields a partition of $\mathbb{F}_q^n$ into such sets.

We will also discuss applications of our construction to a several problems in finite geometry and extremal combinatorics. In particular, we give an improved lower bound for the vector space Ramsey number $R_q(2;k)$ and to the Turán number $ex(n, n^{2/3}, \{C_4, \theta_{3,t}\})$.

Keywords: Line-evasive sets, vector space Ramsey numbers, Turán numbers

MSC(2020): 05D10, 51E22

References

[1] J. Führer, V. Taranchuk. "*Large line-free sets and their applications*", arXiv:2403.18611v2 , 2026.

MSC(2020): 14H37, 14H05.

Large automorphism groups and p-ranks of algebraic curves in characteristic p

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Joint work with: Massimo Giulietti and Gábor Korchmáros

Abstract

In the study of algebraic curves, a fundamental problem is to determine the number of symmetries (or automorphisms) that a given curve can have. This question goes back to the nineteenth century, when significant results were obtained for curves over the complex numbers, particularly through the work of Hurwitz. Much of this theory extends to curves defined over arbitrary fields of characteristic zero, and over the past 125 years the structure and behavior of automorphism groups in this setting have been thoroughly investigated.

In positive characteristic, however, new and remarkable phenomena arise. Automorphism groups may be unexpectedly large compared to the genus of the curve, and the presence of points with stabilizers containing nontrivial p-subgroups (the so-called non-tame case) makes their analysis considerably more involved.

While the relationship between the genus of a curve and its automorphism group is relatively well understood, much less is known about the interaction between automorphism groups and another important birational invariant: the p-rank. In this talk we will delve into this topic and present some recent results in this direction.

Keywords: Algebraic curves, automorphism groups.

References

[1] S. Nakajima. "*p-ranks and automorphism groups of algebraic curves*", Transactions of the American Mathematical Society, **303**, 595-607, 1987.

On Polycyclic Codes over $\frac{\mathbb{F}_{p^m}[u]}{\langle u^t \rangle}$ and their Cardinalities

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Joint work with: Joint work with Pramod Kanwar and Ritumoni Sarma

Abstract

In this article, we study polycyclic codes over the ring $R^t := \frac{\mathbb{F}_{p^m}[u]}{\langle u^t \rangle}$, $t \geq 1$, and their associated torsion codes. We obtain generators of all ideals of the ring $R^{t,\omega} := \frac{\frac{\mathbb{F}_{p^m}[u]}{\langle u^t \rangle}[x]}{\langle \omega(x) \rangle}$, where $\omega(x) \in \frac{\mathbb{F}_{p^m}[u]}{\langle u^t \rangle}[x]$. For the case when $\omega(x) = f(x)^{p^s}$ where $f(x)$ is an irreducible polynomial in $\mathbb{F}_{p^m}[x]$ and s is a non-negative integer, we obtain several other results including computation of torsion ideals and their torsional degrees when $t = 4$. We use the torsional degree to compute the cardinality of polycyclic codes over the ring $\frac{\mathbb{F}_{p^m}[u]}{\langle u^4 \rangle}$. The main result of this article is as follows.

Theorem 1. *Polycyclic codes associated with $\omega(x)$ over R^t, that is, the ideals of the ring $R^{t,\omega}$ and their generators have one of the following forms.*
(a) Trivial ideals $\langle 0 \rangle$, $\langle 1 \rangle$.
(b) Any ideal I contained in $\langle u \rangle$ has the form:

$$I = \langle u^{(t-1)-i_1}(v_1(x)^{k_{1,i_1}} v_2(x)^{k_{2,i_1}} \cdots v_l(x)^{k_{l,i_1}}) - u^{(t-1)-(i_1-1)} g_{i_1}(x), \ldots, \\ u^{(t-1)-i_n}(v_1(x)^{k_{1,i_n}} v_2(x)^{k_{2,i_n}} \cdots v_l(x)^{k_{l,i_n}}) - u^{(t-1)-(i_n-1)} g_{i_n}(x)\rangle,$$

where $0 \leq i_1 < i_2 < \cdots < i_n \leq t-2$, $g_{i_j}(x) \in R^{t,\omega}$ for $1 \leq j \leq n$.
(c) Any non-trivial ideal not contained in $\langle u \rangle$ has the form:

$$\langle (v_1(x)^{k_{1,i}} v_2(x)^{k_{2,i}} \cdots v_l(x)^{k_{l,i}}) + ur(x) \rangle + I,$$

where $r(x) \in R^{t,\omega}$ and I is an ideal as described in (b).

Keywords: Linear Code; Cyclic Code; Constacyclic Code; Finite Chain Ring; Torsion Module

MSC(2020): 94B05, 94B15, 16P70, 13C12

MSC(2020): 11G20, 14G15, 14H05, 14Q05

A formula for the Geil-Matsumoto bound on numerical semigroups

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Joint work with: A. Marques, E. Mendoza, and L. Quoos

Abstract

The Geil-Matsumoto bound (GM bound) constrains the number of rational points on a curve over a finite field in terms of the Weierstrass semigroup of any of the points on the curve. For general numerical semigroups, the GM bound lacks a simple closed-form expression, making its computation a challenging problem. A closed formula has been obtained for the case when the numerical semigroup is generated by two co-prime integers.

In this talk, for any numerical semigroup, we will present a closed formula for the GM bound in terms of the Apéry set of a nonzero element of the semigroup. In the case where the numerical semigroup is generated by consecutive integers $n, n+1, \ldots, n+t$ with $\frac{n-1}{2} \leq t \leq n-1$, we obtain a simple closed formula for the bound. We apply these results to obtain upper bounds on the number of rational points for algebraic curves over finite fields. In some cases, our bounds improve some well-known upper bounds on the number of rational points.

Keywords: Geil-Matsumoto bound, algebraic curves, rational points, Lewittes' bound

References

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Schubert subspace codes from colorings of the q-Johnson graph

Beatrice Toesca

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Joint work with: Gianira Alfarano and Alessandro Neri

Abstract

A constant-dimension subspace code is a subset of the Grassmannian of k-dimensional subspaces in $\mathbb{F}_q^n$, endowed with the subspace distance. The Grassmannian can be partitioned into *Schubert cells*, where each cell contains subspaces with the same shape, given by a *Ferrers diagram*. Using the well-known *multilevel construction* [1], one designs subspace codes by first constructing large codes in some of the cells, and then taking the union. Instead of focusing on individual Schubert cells, *Schubert subspace codes* are codes contained in an entire Schubert variety (the closure of a cell). These codes were first introduced in [2], where constructions were provided of codes with the largest possible subspace distance.

In this talk, we tackle the problem for low values of the subspace distance using notions from graph theory. In the q-Johnson graph and its powers, each vertex is one of the subspaces, and there is an edge between to vertices if the distance between two subspaces is low enough. Using the chromatic number of the graph, for certain parameters we show the existence of Schubert subspace codes achieving the upper bound for the cardinality.

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Covering Radius of Linear Rank-Metric Codes: A Geometric Point of View

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Joint work with: G. Marino and A. Neri

Abstract

The covering radius is an important parameter of a code, but it is generally difficult to determine. Although widely studied in the Hamming metric, much less is known in the rank-metric setting. The covering radius of rank-metric codes was first investigated by Gadouleau and Yan in [2]. More recently, Bonini, Borello and Byrne in [1] introduced a geometric approach using rank-ρ-saturating systems.

In this work, we study the covering radius of linear rank-metric codes from a new geometric perspective. We establish a correspondence with q-systems embedded in higher-dimensional projective spaces and exploit affine hyperplanes to obtain information on the covering radius. Unlike the saturating-system approach, our method relies on the generator matrix of the code, rather than on its parity-check matrix. This approach not only recovers existing results derived from saturating systems but also improves some of them.

Keywords: Rank-metric codes; covering radius; q-systems.

MSC(2020): 05B40, 51E20, 52C17, 11T71, 94B75

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COMBINATORICS 2026
Naples, Italy, 25-29 May 2026

Equivalence of Complex Hadamard Matrices

Tuomo Valtonen

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Joint work with: Patric Östergård

Abstract

Symmetry in the context of equivalence or isomorphism is a fundamental and natural concept in any study of discrete structures. Symmetries are also important for non-discrete structures, but their treatment can be more challenging and is perhaps therefore often overlooked. This holds for many studies of complex Hadamard matrices, that is, matrices with unimodular complex entries satisfying the equation $HH^\dagger = nI$, where $H^\dagger$ is the conjugate transpose of H. In the current work, equivalence of complex Hadamard matrices is considered, and algorithms for determining equivalence of matrices and the automorphism group of a matrix are presented. The algorithms are used to establish the automorphism group of a vast number of complex Hadamard matrices from the literature.

Keywords: Automorphism group, Butson-type Hadamard matrix, complex Hadamard matrix, equivalence

MSC(2020): 05B20

Hoffman colorability of graphs with smallest eigenvalue at least -2

Thijs van Veluw

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Joint work with: Bart De Bruyn

Abstract

In accordance with the Cameron-Goethals-Seidel-Shult Classification Theorem, we extend the characterization of Hoffman colorability of line graphs from [1] to all connected graphs with smallest eigenvalue at least -2; we give a characterization of Hoffman colorability of generalized line graphs, and we completely classify the Hoffman colorable exceptional graphs. The 245 Hoffman colorable exceptional graphs from this classification admit a natural partial ordering, and we determine the 29 graphs that are maximal in this respect, in a way similar to the classification of maximal (E_8-representable) exceptional graphs as described in [2]. Lastly, as a byproduct and also similarly as in [2], we determine all 39 graphs that are maximal with respect to being representable in the E_7 root system.

This talk is based on a submitted article with the same title, which is available at arXiv:2603.03859.

Keywords: Graph coloring, adjacency eigenvalue, line graph, root system

MSC(2020): 05C50,05C15,17B22,05C62

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Is the giant cospectral?

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Joint work with: Alexander Van Werde

Abstract

Haemer's conjecture, which states that almost all graphs are determined by their spectrum, is one of the major open questions in spectral graph theory. It is essentially a statement about dense graphs. We investigate what happens in the sparse regime. The answer to 'Are almost all sparse graphs determined by their spectrum?' seems to depend on the exact density. It is hard to prove that a graph is determined by its spectrum. We know much more about constructions of *cospectral mates*; non-isomorphic graphs with the same spectrum. The most prolific such constructions are so-called switching methods. We show that the giant component of an Erdős–Rényi graph has a cospectral mate when the average degree is sufficiently small. The proof relies on the existence of a specific pendant tree, combined with a method by Schwenk [1] that swaps trees to construct a cospectral mate. It seems possible that pendant trees are essentially the only obstruction, meaning that the giant should become characterized by its spectrum if one considers the 2-core. A proof of this statement would likely be a major breakthrough in proving Haemers' conjecture. However, we do provide some numerical and theoretical evidence of this fact. Our main result shows that local switching methods cannot cause the 2-core to be cospectral. In this talk I will give the background needed to sketch the proofs of our results.

Keywords: Spectral graph theory, sparse random graphs, switching method

MSC(2020): 00X01, 01X02

References

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Pappus configurations in the Hall Plane

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Joint work with: Stefano Lia and John Sheekey

Abstract

It is well-known that a projective plane is coordinatised over a field precisely when it is *Pappian*, where a plane is said to be Pappian if *Pappus' theorem* holds. Pappus' theorem for a plane Π states that all admissible six-tuples in Π form a *Pappus configuration*.

Definition 1. Let ℓ_1 and ℓ_2 be two distinct lines in an affine or projective plane Π and if ℓ_1, ℓ_2 are not parallel, let $X = \ell_1 \cap \ell_2$. Let P_1, P_2, P_3 be distinct points, different from X, on ℓ_1 and let Q_1, Q_2, Q_3 be distinct points, different from X, on ℓ_2. Then the ordered set of points $(P_1, P_2, P_3, Q_1, Q_2, Q_3)$ are said to be form a *Pappus configuration* if and only if the points $R_1 = P_2Q_3 \cap P_3Q_2$, $R_2 = P_1Q_3 \cap P_3Q_1$, and $R_3 = P_1Q_2 \cap P_2Q_1$ are collinear in Π.

The fact that Pappus' theorem fails in the finite Hall plane (which is not Pappian) doesn't preclude the existence of Pappus configurations. We will use the geometric model of the finite affine Hall plane to show that for any two lines ℓ_1, ℓ_2 and for any triple of points on ℓ_1 there is a triple of points on ℓ_2 that are contained in a Pappus configuration, thus improving on the results of [1].

Keywords: Pappus' theorem, Hall plane

MSC(2020): 51E15

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Naples, Italy, 25-29 May 2026

Hierarchical Locally Recoverable Codes on surfaces

Lara Vicino
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Joint work with: C. Araujo, L. Costa, B. Malmskog, J. Mello, E. Menezes, C. Salgado

Abstract

We construct Locally Recoverable Codes with hierarchy from surfaces in $\mathbb{A}^3$ admitting a fibration by curves of Artin-Schreier or Kummer type. We derive the parameters of our codes by leveraging the geometry and arithmetic of the fibration, which is obtained by projection onto one of the coordinates. As a byproduct, we obtain estimates for (and in one case an explicit count of) the number of rational points in certain families of surfaces.

Keywords: Locally Recoverable Codes; hierarchy; fibered surfaces; Artin-Schreier curves; Kummer curves

References

[1] C. Araujo, L. Costa, B. Malmskog, J. Mello, E. Menezes, C. Salgado. "*Hierarchical Locally Recoverable Codes on surfaces*", arXiv preprint arXiv:2602.01464, 2026.

MSC(2020): 11G20, 14G50, 94B27

An application of signed graphs to crop production with different species in the same parcel

Andrea Vietri

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Abstract

Signed graphs arise in graph theory as a formal way of representing positive or negative interactions between elements of a given set. For this reason, they are particularly suitable in Agronomy issues where positive or negative effects between plants are the object of study. Using the language of signed graphs we address a classical question related to intercropping, a well known topic in Agronomy. We describe and manage mutual benefits between different species of crop planted at a short distance, as well as negative effects of too close placements in a soil cultivation. We construct a model starting from a given companion planting chart together with a sawing-harvesting calendar and we present, as the main result, an algorithm which works out optimal intercroppings for a given number of species in some given parcels, taking into account the mutual benefits and the plant vigor which varies along the year and depends also from the species.

Keywords: Graph theory, Signed graph, Intercropping, Companion planting.

MSC(2020): 05C22, 05C90.

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Counting the quadratic relations for a vectorial Boolean function

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Abstract

Given two vectorial Boolean functions, determining whether they are CCZ equivalent is often a challenging task, both computationally and theoretically. Finding CCZ invariants, easy to compute, help in this regard. In this work, we consider the notion of quadratic relation, a relation of degree at most two between the input and the output variables of a function. We prove that the number of linearly independent quadratic relation satisfied by a vectorial Boolean functions is CCZ invariant. In particular, we study the case of CCZ quadratic functions, that are functions CCZ equivalent to quadratic maps. We prove bounds on the number of linearly independent quadratic relations satisfied by a CCZ quadratic function. These necessary conditions can be checked also in relatively large dimensions, since the quadratic relations are obtained through the solution of a linear system.

Definition 1. Given a vectorial Boolean function $F : \mathbb{F}_2^n \to \mathbb{F}_2^m$, a quadratic relation for F is a function $\mathcal{R} : \mathbb{F}_2^n \times \mathbb{F}_2^m \to \mathbb{F}_2$ of the form

$$\mathcal{R}(z,w) = \sum_{1\le i<j\le n} \alpha_{ij} z_i z_j + \sum_{\substack{1\le i\le n \\ 1\le j\le m}} \beta_{ij} z_i w_j + \sum_{1\le i<j\le m} \gamma_{ij} z_i z_j + \sum_{1\le i\le n} \delta_i z_i + \sum_{1\le i\le m} \zeta_i w_i + \varepsilon$$

such that for any $\bar{z} \in \mathbb{F}_2^n$, setting $\bar{w} = F(\bar{z})$, it holds that $\mathcal{R}(\bar{z}, \bar{w}) = 0$.

Our main result is the following.

Theorem 2. *The number λ of linearly independent quadratic relations is a CCZ invariant. Therefore, if the function is CCZ quadratic with $2^k - 1$ affine components, then $\lambda \ge k(n+m) - \frac{k(k+1)}{2} + m$.*

Keywords: vectorial Boolean functions; CCZ invariant; quadratic relations

MSC(2020): 11T06, 11T71

Computational combinatorial construction with `solvediophant`

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Abstract

With the software `solvediophant`, implemented by the author, many combinatorial objects could be constructed over the years. Among them were the first combinatorial designs for $t = 7, 8, 9$, subspace designs, designs in polar spaces, linear codes and boolean degree d functions, to name a few.

The search for combinatorial objects can often be reduced to solving a system of linear equations $M \cdot x = b$ in $\{0, 1\}$ variables and `solvediophant` has been optimized to solve such systems. In particular, if the entries of the right hand side vector b are large, the algorithm seems to perform well.

In the talk, new developments will be discussed, e.g. the use of least discrepancy search. `solvediophant` is open source and available at github.

Keywords: Combinatorial search; Integer linear optimization; Design theory

MSC(2020): 05-04,05-08

References

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[3] Alfred Wassermann. "*Solving the market split problem with lattice enumeration*", arXiv 2508.08702, 2025.

Multisets with few determined directions and small weight codewords in Desarguesian planes

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Joint work with: Sam Adriaensen and Tamás Szőnyi

Abstract

For a set $S \subseteq \mathrm{AG}(2,q)$, $q = p^h$, with $|S| = nq$, a direction m is called *equidistributed* if every line of slope m meets S in exactly n points. Ghidelli asked for the possible numbers of non-equidistributed directions. The case $n = 1$ is the well-studied question in finite geometry: the number of directions determined by a point set of size q. While Ghidelli, Kiss and Somlai investigated this question primarily for $q = p$ prime, we generalize this framework to arbitrary prime powers and extend the scope to multisets. Furthermore, we introduce the modular version of the problem, considering directions where line intersections are the same modulo p. We establish the connection between multisets with few determined directions (in a modular sense) and small-weight codewords of the linear code generated by the incidence matrix of $\mathrm{PG}(2,q)$.

The problem of sets determining few directions is, in fact, a special case of a more general question posed by Erdős. Originally, Erdős asked for the maximum number of balanced lines (lines containing an equal number of red and blue points) in a two-colored projective plane. We consider a generalized version of this problem and, time permitting, we shall present stability results characterizing all colorings that admit only a small number of unbalanced lines.

Keywords: finite geometry, directions, coding theory.

MSC(2020): 05B25, 94B05

References

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MSC(2020): 05C20, 05C30

The number of reachable pairs in a digraph

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Joint work with: Eric Swartz

Abstract

A pair (u, v) of (not necessarily distinct) vertices in a directed graph D is called a reachable pair if there exists a directed path from u to v. We define the weight of D to be the number of reachable pairs of D, which equals the sum of the number of vertices in D and the number of directed edges in the transitive closure of D. In this talk, we examine the set $W(n)$ of possible weights of directed graphs on n labeled vertices. It is clear that $W(n) \subseteq \{x \in \mathbb{N} \mid n \leq x \leq n^2\}$, but for $n \geq 3$ we have $W(n) \neq \{x \in \mathbb{N} \mid n \leq x \leq n^2\}$, which means that not every integer between n and n^2 occurs as a weight. We prove that $W(n)$ can be determined recursively and describe the integers in the set. Moreover, we show that the majority of the values in $W(n)$ lie in an interval of $\mathbb{N}$ that can be computed recursively and independently of $W(n)$ itself. Connections and applications to other structures such as matrix rings, preorders, and topologies on finite spaces will be discussed.

A new construction of divisible design graphs from distance-regular graphs related to the classical Ree groups and Suzuki groups

Yilin Xie

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Joint work with: Bart De Bruyn and Sergey Goryainov

Abstract

We consider only simple graphs. A *divisible design graph* with parameters $(v, k, \lambda_1, \lambda_2, m, n)$ is a k-regular graph on v vertices such that its vertex set can be partitioned into m classes of size n where any two distinct vertices from the same class have exactly λ_1 common neighbours and any two vertices from different classes have exactly λ_2 common neighbours. Divisible design graphs were introduced in [1] as a bridge between graph theory and theory of group divisible designs. Since then, tens of constructions of divisible design graphs have been introduced.

In this talk, we present a new construction of divisible design graphs obtained by plugging a difference set into a construction of antipodal distance-regular graphs of diameter 3 from coset graphs of Suzuki and Ree groups [2].

Keywords: divisible design graph; Ree group; Suzuki group

MSC(2020): 05C25, 05B05, 05E30

References

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MSC(2020): 05B35, 51E22, 94B05

On the representability of the direct sum of (near-)uniform q-matroids

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Joint work with: Giovanni Longobardi and Rocco Trombetti

Abstract

A q-matroid is said to be *paving* if all of its *circuits* have dimension at least equal to the *rank* of the q-matroid itself [2]. Also in [2], the authors focus on the so called *representability* issue for such a class of q-matroids and exhibit several examples which are not representable. On the other hand, it is well known that *uniform* q-matroids, satisfying some restrictions on the relevant involved parameters, are representable via maximum rank distance codes. Moreover, they are also readily verified to be paving q-matroids.

The representability problem for paving q-matroids remains open in general [2, Section 4]. Building on the geometric characterization of near-MRD codes, we elaborate on the structure of the associated q-matroids. In particular, we determine their cyclic flats and identify them as representable q-matroids.

Furthermore, as done in [1], we study the direct sum of two q-matroids where each summand is either a uniform or a near-uniform q-matroid and we derive necessary and sufficient geometric conditions for its representability.

Keywords: paving q-matroids; representability; rank-metric codes; near-MRD codes

References

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Quaternary codes with improved parameters from Simplicial Complexes

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Joint work with: N. K. Mondal and R. Sarma

Abstract

The study of quaternary codes has remained an active area of research since the seminal article by Hammons et al. [1], which demonstrated that several well-known nonlinear binary codes–such as the Kerdock and Preparata codes–can be realized as Gray images of $\mathbb{Z}_4$-linear codes.

More recently, Wu et al. [2] used simplicial complexes to construct infinite families of quaternary linear codes and obtained examples of new quaternary codes, as per the database of best-known quaternary codes.

In this talk, we will present three infinite families of quaternary linear codes constructed from two-generator simplicial complexes, determine their Lee weight distributions, and one of these families is Lee weight projective. Moreover, we obtain a Plotkin-optimal family and at least 32 new or improved quaternary linear codes as per the database.

Keywords: Quaternary code, simplicial complex, projective code

References

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MSC(2020): 94B05, 94B25, 94B60, 11T71

MSC(2020): 94B35, 94B05, 14M15

Majority Logic Decoding of Affine Grassmann Codes Over Nonbinary Fields

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Joint work with: Fernando Pinero and Prasant Singh

Abstract

Affine Grassmann codes $C^{\mathbb{A}}(\ell, m)$ are linear codes obtained from the $\mathbb{F}_q$-rational points of an affine open subset of the Grassmannian [1]. While their parameters and structure are well studied, decoding has remained open.

We propose the majority logic decoder for these codes over nonbinary fields. Using the large automorphism group and geometric properties of rank-r matrices, we construct orthogonal parity checks for each coordinate. These checks arise from carefully chosen sets of matrices whose supports are disjoint except for a common coordinate, enabling orthogonalization. By the transitive action of the automorphism group, orthogonal checks are obtained for every coordinate.

For $q \geq 3$, we produce a large number of orthogonal parity checks on any coordinate. Majority logic decoding then corrects up to half this number of errors, which asymptotically reaches $d/2^{\ell+1}$, where d is the minimum distance.

Keywords: Affine Grassmann codes; Majority logic decoding

References

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A new construction of divisible design graphs and strongly regular graphs from Mathon distance-regular graphs

Weihao Yan

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Joint work with: Aida Abiad, Bart De Bruyn, Sergey Goryainov and Thijs van Veluw

Abstract

We consider only simple graphs. A *divisible design graph* with parameters $(v, k, \lambda_1, \lambda_2, m, n)$ is a k-regular graph on v vertices such that its vertex set can be partitioned into m classes of size n where any two distinct vertices from the same class have exactly λ_1 common neighbours and any two vertices from different classes have exactly λ_2 common neighbours. Divisible design graphs were introduced in [1] as a bridge between graph theory and theory of group divisible designs. Since then, tens of constructions of divisible design graphs have been introduced.

In this talk, we present a new construction of divisible design graphs obtained by plugging a (relative, divisible) difference set into the Mathon construction of antipodal distance-regular graphs of diameter 3. In some special cases, we get new strongly regular graphs.

Keywords: divisible design graph; strongly regular graph; difference set

MSC(2020): 05C25, 05B05, 05E30

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MSC(2020): 16S36, 11T71, 94B05

A Sum-Rank Analogue of Reed-Muller Codes

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Joint work with: A. Neri

Abstract

Sum-rank metric codes were introduced in multishot network coding and provide a unified framework encompassing both the Hamming and rank metrics. They can be represented through univariate skew polynomials over cyclic Galois extensions, a representation that led to the construction of linearized Reed–Solomon codes [2], the sum-rank analogue of Reed–Solomon codes.

In this work, we study sum-rank metric codes via an auxiliary Abelian Galois extension. This yields an algebraic representation in which codewords are interpreted as elements of a multivariate skew polynomial ring. Using this framework, we introduce a new sum-rank analogue of Reed–Muller codes, preserving key features of classical Reed–Muller codes in the Hamming metric. Our main tool is a generalization of the Alon–Füredi bound to multivariate skew polynomials, building on previous results on rank-metric codes over arbitrary Galois extensions [1].

Keywords: Sum-rank metric; Skew polynomials.

References

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New families of ordinary curves with many automorphisms

Giovanni Zini

University of Modena and Reggio Emilia (Italy)

Joint work with: H. Borges and J. Tilling

Abstract

Algebraic curves in positive characteristic admitting many automorphisms are an active research topics, because of theoretical and applicative reasons. Ordinary algebraic curves of genus g have at most $\approx g^2$ automorphisms [1], and improvements on this bound have being investigated in recent years, depending on group-theoretical properties of the automorphism group. Yet, not many families of ordinary curves having more than $\approx g$ are known in the literature.

We present some new families of ordinary curves $\mathcal{X}$ obtained as multiple Artin-Schreier extensions of rational curves $\mathcal{C}$, starting from easy examples where $\mathcal{C}$ is a plane conic. The goal is to "lift" to $\mathcal{X}$ large automorphism groups of $\mathcal{C}$, which are subgroups of the projective linear group $\mathrm{PGL}(2, q)$ for some prime power q. Indeed, we construct infinite families where the size of the automorphism group is around $g^{4/3}$, $g^{3/2}$ and $g^{5/3}$.

For some families, we also prove that the constructed automorphism group is in fact the full automorphism group of the curve.

This is a joint work [2] with Herivelto Borges and Jonathan Tilling.

Keywords: algebraic curves; automorphism groups; Artin-Schreier extensions.

MSC(2020): 14H05, 14H37

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The square span of a subspace and quadrics over finite fields

Ferdinando Zullo

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Joint work with: Chiara Castello, Alain Couvreur and Olga Polverino

Abstract

We study finite-dimensional subspaces of finite field extensions with small square span, a parameter that measures the multiplicative structure generated by the subspace. Our approach establishes a geometric correspondence between such subspaces and linear systems of quadrics in projective space. In particular, fixing a basis of the subspace determines a point in projective space, and the quadrics defined over the base field passing through this point encode the dimension of the square span. This geometric perspective allows us to translate multiplicative properties of subspaces into properties of algebraic varieties defined by these quadrics. In particular, we characterize subspaces admitting bases in geometric progression, and we investigate the structure of subspaces with small square span. As an application, we analyze in detail the case of four-dimensional subspaces.

Keywords: Finite field; Quadrics in projective space; Square span

MSC(2020): 11T30; 14N05

Point-line approach to symmetric $(15, 8, 4)$-designs and their automorphisms

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Joint work with: Mark Pankov, Krzysztof Petelczyc

Abstract

Those points of a projective space over the two-element field, which all have a fixed even Hamming weight, form a point-line geometry whose maximal singular subspaces correspond to binary equidistant codes, say of dimension k, cf. [1]. The collinearity graph of this geometry is the generalized Johnson graph $\mathrm{J}(2^k - 1, 2^{k-1}, 2^{k-2})$ and its $(2^k - 1)$-cliques are exactly the sets of blocks of symmetric $(2^k - 1, 2^{k-1}, 2^{k-2})$-designs. For $k = 4$ the classification of cliques leads to a simple description of the five symmetric $(15, 8, 4)$-designs, all in terms of point-line geometry where Fano planes play a critical part, cf. [2]. Taking advantage of this description we are able to determine the automorphism groups of all five symmetric $(15, 8, 4)$-designs and describe their actions on the sets of points and blocks.

Keywords: point-line geometry; collinearity graph; equidistant code; symmetric block design

MSC(2020): 51E20, 51E22

References

[1] M. Pankov, K. Petelczyc, M. Żynel, *Point-line geometry related to binary equidistant codes*, J. Combin. Theory, Ser. A 210 (2025), 105962.

[2] M. Pankov, K. Petelczyc, M. Żynel, *Symmetric* $(15, 8, 4)$*-designs in terms of the geometry of binary simplex codes of dimension* 4, Des. Codes Cryptography 93 (2025), 1761-1775.

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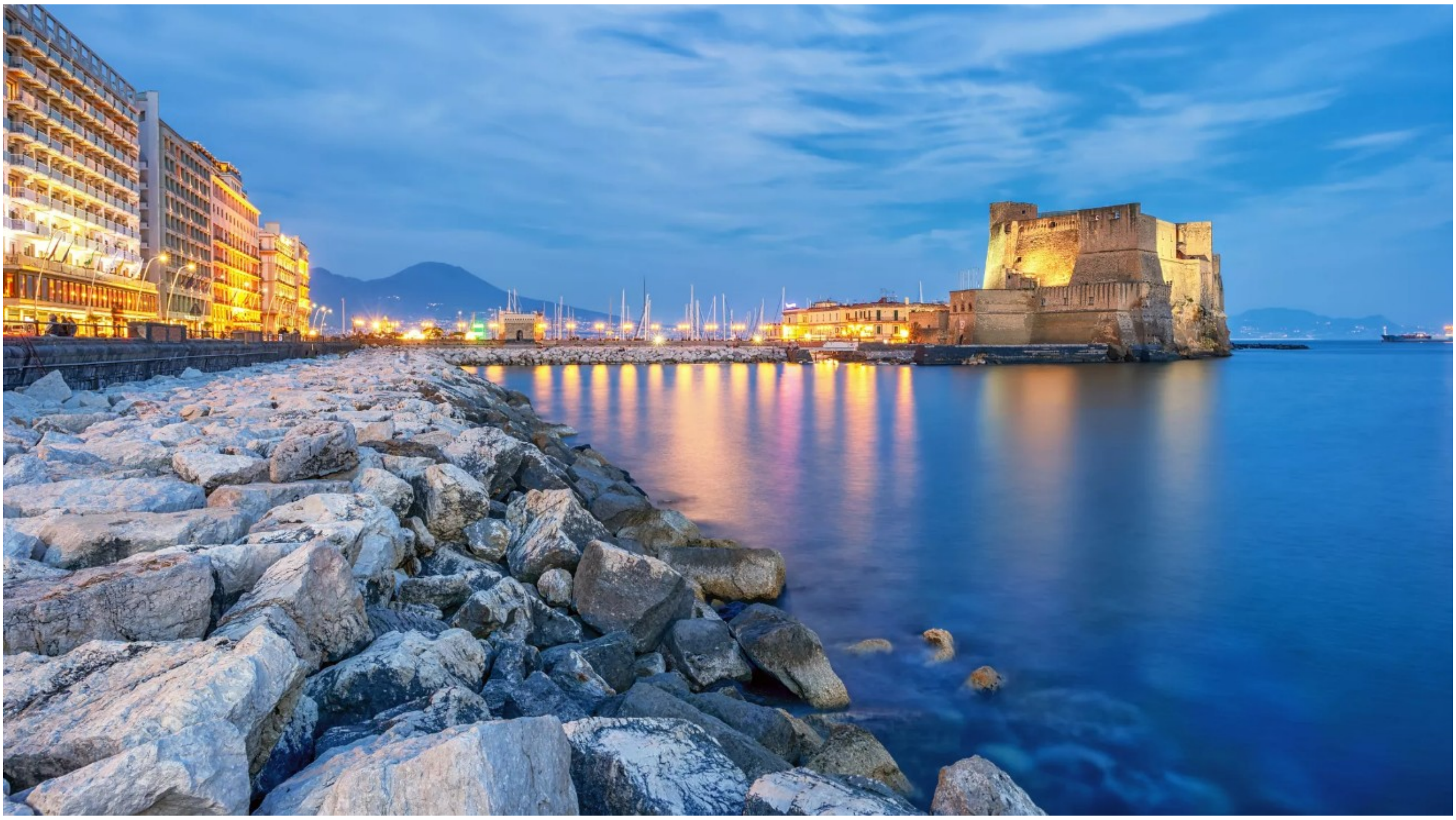

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