The book of abstracts

Combinatorial Designs and Codes

Satellite event of the 8th European Congress of Mathematics

11 July – 16 July 2021

Rijeka, Croatia

Time zone: CEST (GMT+2)

UNIVERSITY OF RIJEKA
DEPARTMENT OF MATHEMATICS

General information

The goal of the conference is to bring together researchers interested in combinatorial designs, algebraic combinatorics, finite geometry, graphs, and their applications to communication and cryptography, especially to codes (error-correcting codes, quantum codes, network codes, etc.).

The main topics of the conference are: construction of combinatorial designs and strongly regular graphs, including constructions from finite groups and codes, construction of linear codes from graphs and combinatorial designs, network codes related to combinatorial structures; Hadamard matrices, association schemes, codes, designs, and graphs related to finite geometries, q-analogues of designs and other combinatorial structures.

Organizing Committee:

- Dean Crnković (deanc@math.uniri.hr)
- Vedrana Mikulić Crnković (vmikulic@math.uniri.hr)
- Sanja Rukavina (sanjar@math.uniri.hr)
- Andrea Švob (asvob@math.uniri.hr)

Website:
https://cdc2020-math.uniri.hr/

Conference programme

Time zone: CEST (GMT+2)

Monday, 12 July

13:55-14:00 Opening

14:00-14:50 **W. Haemers: Spectral characterizations for regular graphs**

14:50-15:00 Break

15:00-15:20 Edwin R. van Dam: Unit gain graphs with two distinct eigenvalues and systems of lines in complex space

15:20-15:40 Pepijn Wissing: A Hermitian adjacency matrix for Signed Directed Graphs

15:40-16:00 Vladislav Kabanov: Constructions of divisible design Cayley graphs

16:00-16:20 Maarten De Boeck: Neumaier graphs

16:20-16:40 Tianxiao Zhao: On the non-existence of srg(85,14,3,2) and the Euclidean representation

16:40-17:00 Nina Mostarac: Distance-regular graphs from the Mathieu groups

17:00-17:50 **C. Colbourn: Double, double toil and trouble**

17:50-18:00 Break

18:00-18:20 K. T. Arasu: Unimodular Perfect and Nearly Perfect Sequences: A Variation of Björck's Scheme

18:20-18:40 Simone Costa: Generalizations of Heffter arrays and biembedding (multi)graphs on surfaces

18:40-19:00 Raúl M. Falcón: On the fractal dimension of strongly isotopism classes of Latin squares

19:00-19:20 Letong Hong: A Markov chain on the solution space of edge–colorings of bipartite graphs

Tuesday, 13 July

14:00-14:50 **M. Buratti: Tales from my diary of symmetries**

14:50-15:00 Break

15:00-15:20 John R. Schmitt: New methods to attack the Buratti-Horak-Rosa conjecture

15:20-15:40 Alessandro Montinaro: On flag-transitive symmetric 2-(v, k, λ) designs

15:40-16:00 Wojciech Bruzda: Quantum Solution to the Problem of 36 Officers of Euler

16:00-16:20 Peter Danziger: Cycle Decompositions of Complete Digraphs

16:20-16:40 David Pike: Perfect 1-Factorisations

16:40-17:00 Andrea Burgess: On the spouse-loving variant of the Oberwolfach Problem

17:00-17:50 **H. Kharaghani: Constructing some combinatorial matrices by using orthogonal arrays**

17:50-18:00 Break

18:00-18:20 Ronan Egan: On the Hadamard maximal determinant problem

18:20-18:40 Ivan Bailera: Butson Hadamard full propelinear codes

18:40-19:00 Thomas Y. Chen: Speeding up Inference in Machine Learning Algorithms using Hadamard Matrices

Wednesday, 14 July

14:00-14:50 **L. Storme: Erdős-Ko-Rado, Cameron-Liebler and Hilton-Milner results in finite projective spaces**

14:50-15:00 Break

15:00-15:20 Ivan Mogilnykh: Completely regular codes in Johnson and Grassmann graphs with small covering radii

15:20-15:40 Daniel Hawtin: Neighbour-transitive codes in generalised quadrangles

15:40-16:00 Jonathan Mannaert: Cameron-Liebler line classes in AG(3,q)

16:00-16:20 Francesco Pavese: Small complete caps in PG(4n+1,q)

16:20-16:40 Ferdinando Zullo: The geometric counterpart of maximum rank metric codes

16:40-17:00 Sam Mattheus: Eigenvalues of oppositeness graphs and Erdős-Ko-Rado for flags

17:00-17:50 **V. Tonchev: Pless symmetry codes, ternary QR codes, and related Hadamard matrices and designs**

17:50-18:00 Break

18:00-18:20 Patrick Solé: Bounds on permutation designs

18:20-18:40 Shuxing Li: Intersection Distribution and Its Application

18:40-19:00 Tin Zrinski: S(2,5,45) designs constructed from orbit matrices using a modified genetic algorithm

Thursday, 15 July

14:00-14:50 **A. Wassermann: Linear Codes from q-analogues in Design Theory**

14:50-15:00 Break

15:00-15:20 Michael Kiermaier: On α-points of q-analogs of the Fano plane

15:20-15:40 Kristijan Tabak: On Automorphisms of a binary Fano plane

15:40-16:00 Relinde Jurrius: Constructions of new matroids and designs over $\mathbb{F}_q$

16:00-16:20 Miguel Ángel Navarro-Pérez: A Combinatorial Approach to Flag Codes

16:20-16:40 Domenico Labbate: Extending perfect matchings to Hamiltonian cycles in line graphs

16:40-16:50 Break

16:50-17:10 Renata Vlahović Kruc: Quasi-symmetric 2-(28,12,11) designs with an automorphism of order 5

17:10-17:30 Vedran Krčadinac: On 4-designs with three intersection numbers

17:30-17:50 Krystal Guo: Entanglement of free Fermions on distance-regular graphs

17:50-18:10 Marina Šimac: On some LDPC codes

18:10-18:30 Ana Grbac: On some constructions of LCD codes

Friday, 16 July

14:00-14:50 **M. Greferath: Group Testing as Coding over the binary semifield via Residuation Theory**

14:50-15:00 Break

15:00-15:20 Faina Solov'eva: Reed-Muller like codes and their intersections

15:20-15:40 Ludmila Tsiovkina: On abelian distance-regular covers of complete graphs related to rank 3 permutation groups

15:40-16:00 Eric Swartz: Restrictions on parameters of partial difference sets in nonabelian groups

16:00-16:20 Marko Orel: A family of non-Cayley cores that is constructed from vertex-transitive or strongly regular self-complementary graphs

16:20-16:40 Sara D. Cardell: Counting erasure patters of SPC product codes by means of bipartite graphs

16:40-17:00 Sara Ban: A construction of $\mathbb{Z}_4$-codes from generalized bent functions

17:00-17:20 Matteo Mravić: On extremal self-dual $\mathbb{Z}_4$-codes

17:20-17:30 Closing

Invited speakers

1. Marco Buratti, University of Perugia, Italy
2. Charles Colbourn, Arizona State University, Arizona, USA
3. Marcus Greferath, University College Dublin, Ireland
4. Willem Haemers, Tilburg University, The Netherlands
5. Hadi Kharaghani, University of Lethbridge, Canada
6. Leo Storme, Ghent University, Belgium
7. Vladimir Tonchev, Michigan Technological University, Houghton, Michigan, USA
8. Alfred Wassermann, University of Bayreuth, Germany

Tales from my diary of symmetries

Marco Buratti

University of Perugia

I would like to give a roundup of problems, conjectures, unpublished results and autobiographic stories concerning my favorite math subject, that is combinatorial designs with many symmetries.

Double, double toil and trouble

Charles J. Colbourn

Arizona State University, Tempe, Arizona, USA

To achieve access balancing for distributed storage systems, both the points and blocks of a design are linearly ordered, computing each *point sum* as the sum of the indices of blocks containing that point and each *block sum* as the sum of the indices of points contained in that block. Popularity block (point) ordering asks for the point (resp., block) sums to be as equal as possible. In this talk, we discuss popularity orderings for Steiner quadruple systems ($S(3,4,v)$ designs). First we observe that a well-known doubling construction establishes bounds on block sums of SQSs. Then we adapt the doubling construction to yield bounds on point sums that provide optimal popularity block orderings for $SQS(v)$s whenever $v \equiv 4, 8 \pmod{12}$ and $v > 8$.

Group Testing as Coding over the binary semifield via Residuation Theory

Marcus Greferath

School of Mathematics and Statistics
University College Dublin
Republic of Ireland

We present a novel approach to (non-adaptive) group testing by describing it in terms of residuated pairs on partially ordered sets. The resulting efficient decision scheme covers large classes of group testing schemes for pandemic diseases during the initial low prevalence phase.

Our design of the testing schemes is based on incidence matrices of finite (partial) linear spaces. The results may be tailored for different estimated disease prevalence levels. The key idea is that by building sufficient structure into the test-design matrix, one may increase what may be called the efficiency of the testing.

We also observe that generalized quadrangles are of significant advantage in comparison with other types of block designs. For simplicity, we state our results when the tests are error-free. An adaptation to a low error-rate scenario is actually beyond the scope of this work but will briefly discussed in a final section.

Joint work with Cornelia Roessing.

Spectral characterizations for regular graphs

Willem Haemers

Tilburg University, The Netherlands

An important activity in algebraic graph theory is to establish which properties are characterized by the spectrum of the adjacency matrix. Of special interest are properties that include regularity. Two famous examples of such problems are: Being strongly regular, and being the incidence graph of a projective plane. We will survey several of these properties. The focus will be on counter examples which consist of pairs of cospectral regular graphs, where one has a given property and the other one not. We will also show existence of NP-hard graph properties which are characterized by the spectrum.

Constructing some combinatorial matrices by using orthogonal arrays

Hadi Kharaghani

University of Letbridge, Lethbridge, Canada

A unified method is used to construct weighing matrices, balanced weighing matrices, balanced generalized weighing matrices, and symmetric designs. These include:

- Assuming the weight p in a seed weighing matrix $W(n,p)$ is a prime power, then there is a
$$W\left(\frac{p^{m+1}-1}{p-1}(n-1)+1, p^{m+1}\right)$$
for each positive integer m. The case of $n=p+1$ reduces to the balanced weighing matrices with classical parameters
$$W\left(\frac{p^{m+2}-1}{p-1}, p^{m+1}\right).$$

- Assuming the existence of a seed twin $SBIBD(2p+1, p, \frac{p-1}{2})$, p an odd prime power, then there is a
$$SBIBD\left(2p(\frac{p^{m+1}-1}{p-1})+1, p^{m+1}, p^m(\frac{p-1}{2})\right)$$
for each positive integer m.

- Assuming the existence of a seed $SBIBD(n^2+n+1, n+1, 1)$, $n+1$ a prime power, then there is a
$$SBIBD\left((b-1)\frac{a^k-1}{a-1}+1, a^k, a^k(fraca-1b-1)\right),$$
where $a=\frac{n^m-1}{a-1}$, $b=\frac{n^{m+1}-1}{n-1}$, m,n arbitrary positive integers.

Erdős-Ko-Rado, Cameron-Liebler and Hilton-Milner results in finite projective spaces

Leo Storme

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Let $\mathrm{PG}(n,q)$ be the projective space of dimension n over the finite field $\mathbb{F}_q$ of order q.

An *Erdős-Ko-Rado k-set* in $\mathrm{PG}(n,q)$ is a set of k-spaces, pairwise intersecting in at least one point. Here, the main problem is to characterize the largest Erdős-Ko-Rado k-sets in $\mathrm{PG}(n,q)$.

Cameron-Liebler k-sets in $\mathrm{PG}(n,q)$ can be defined in many equivalent ways. For instance, if $(k+1)|(n+1)$ and k-spreads exist in $\mathrm{PG}(n,q)$, a *Cameron-Liebler k-set in $PG(n,q)$ with parameter x* is a set of k-spaces sharing always exactly x k-spaces with every k-spread in $\mathrm{PG}(n,q)$. Here, the main problem is to investigate whether Cameron-Liebler k-sets in $\mathrm{PG}(n,q)$ with parameter x exist, and if such Cameron-Liebler k-sets exist, to characterize Cameron-Liebler k-sets in $\mathrm{PG}(n,q)$ with parameter x.

One of the interesting facts about these two types of substructures in finite projective spaces is that many techniques from algebraic combinatorics can be used to investigate these substructures.

This talk will present results on these two types of substructures, showing the great relevance of algebraic combinatorics for finite geometry.

The *Hilton-Milner* problem in $\mathrm{PG}(n,q)$ regards the characterization of the second largest maximal Erdős-Ko-Rado k-sets in $\mathrm{PG}(n,q)$. Hilton-Milner results have proven to be very useful to derive results on Cameron-Liebler k-sets in $\mathrm{PG}(n,q)$, showing the interaction between all these types of substructures.

Pless symmetry codes, ternary QR codes, and related Hadamard matrices and designs

Vladimir D. Tonchev

Michigan Technological Universityn

We consider a code $L(q)$ which is monomially equivalent to the Pless symmetry code $C(q)$ of length $2q+2$ that contains the (0,1)-incidence matrix of a Hadamard 3-$(2q+2, q+1, (q-1)/2)$ design $D(q)$ associated with a Paley-Hadamard matrix of type II. Similarly, any ternary extended quadratic residue code contains the incidence matrix of a Hadamard 3-design associated with a Paley-Hadamard matrix of type I. If $q = 5, 11, 17$ and 23 then the full permutation automorphism group of $L(q)$ coincides with the full automorphism group of $D(q)$, and a similar result holds for the ternary extended quadratic residue codes of lengths 24 and 48. All Hadamard matrices of order 36 formed by codewords of the Pless symmetry code $C(17)$ are enumerated and classified up to equivalence. There are two equivalence classes of such matrices: the Paley-Hadamard matrix H of type I with a full automorphism group of order 19584, and a second regular Hadamard matrix H' such that the symmetric 2-$(36, 15, 6)$ design D associated with H' has trivial full automorphism group, and the incidence matrix of D spans a ternary code equivalent to $C(17)$.

Linear Codes from q-analogues in Design Theory

Alfred Wassermann

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In 1967, Rudolph presented a decoding method for linear codes based on majority decision with *non-orthogonal* parity check equations. Whenever a linear code has a point-block incidence matrix of a combinatorial design (with $t \geq 2$) as a parity check matrix, this decoder can be used.

These linear codes from combinatorial designs are only interesting if the p-rank of the point-block incidence matrix is small enough. Hamada (1973) determined the p-rank for the incidence matrices of the so-called classical or geometric designs. It is a long-standing conjecture that the incidence matrices from this class of designs are of minimal p-rank.

In this talk we will show that linear codes from subspace designs (q-analogues of combinatorial designs) are at least as good to decode with Rudolph's method as the linear codes from their corresponding geometric designs, but for many parameters the decoder needs exponentially less parity check equations.

Now, an obvious step is to search for q-analogues of other combinatorial structures and study the linear codes from their incidence matrices. In this talk, we will explore q-analogues of group divisible designs, lifted MRD codes and designs in polar spaces and show how those objects fit into the picture.

Contributed talks

1. K. T. Arasu: Unimodular Perfect and Nearly Perfect Sequences: A Variation of Björck's Scheme
2. Ivan Bailera: Butson Hadamard full propelinear codes
3. Sara Ban: A construction of $\mathbb{Z}_4$-codes from generalized bent functions
4. Maarten De Boeck: Neumaier graphs
5. Wojciech Bruzda: Quantum Solution to the Problem of 36 Officers of Euler
6. Andrea Burgess: On the spouse-loving variant of the Oberwolfach Problem
7. Sara D. Cardell: Counting erasure patters of SPC product codes by means of bipartite graphs
8. Thomas Y. Chen: Speeding up Inference in Machine Learning Algorithms using Hadamard Matrices
9. Simone Costa: Generalizations of Heffter arrays and biembedding (multi)graphs on surfaces
10. Edwin R. van Dam: Unit gain graphs with two distinct eigenvalues and systems of lines in complex space
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24. Jonathan Mannaert: Cameron-Liebler line classes in $AG(3, q)$
25. Sam Mattheus: Eigenvalues of oppositeness graphs and Erdős-Ko-Rado for flags
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28. Nina Mostarac: Distance-regular graphs from the Mathieu groups
29. Matteo Mravić: On extremal self-dual $\mathbb{Z}_4$-codes
30. Miguel Ángel Navarro-Pérez: A Combinatorial Approach to Flag Codes
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32. Francesco Pavese: Small complete caps in $PG(4n + 1, q)$
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34. John R. Schmitt: New methods to attack the Buratti-Horak-Rosa conjecture
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37. Eric Swartz: Restrictions on parameters of partial difference sets in nonabelian groups

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41. Renata Vlahović Kruc: Quasi-symmetric 2-(28,12,11) designs with an automorphism of order 5
42. Pepijn Wissing: A Hermitian adjacency matrix for Signed Directed Graphs
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44. Tin Zrinski: S(2,5,45) designs constructed from orbit matrices using a modified genetic algorithm
45. Ferdinando Zullo: The geometric counterpart of maximum rank metric codes

Unimodular Perfect and Nearly Perfect Sequences: A Variation of Björck's Scheme

K. T. Arasu

Riverside Research 2640 Hibiscus Way Beavercreek, OH 45431, USA

Constant Amplitude (CA), Zero Auto Correlation (ZAC) sequences (or CAZAC sequences, aka perfect sequences) have numerous applications: linear system parameter identification, real-time channel evaluation, synchronization, timing measurements, direct-sequence spread spectrum multiple access (DS/SSMA), frequency hopped spread-spectrum multiple access (FH/SSMA), and two-dimensional processing. The study of CAZAC property originates in radar and communication theory. The constant amplitude property ensures the ability to transmit signals at peak power constantly, while the zero autocorrelation property ensures that returning radar signals do not interfere with outgoing signals. We investigate Björck sequences, which are CAZAC. We also generalize these notions to what we term as CASAC by permitting small autocorrelations (SAC). Out-of-phase periodic auto-correlation values of these Björck-like CASAC sequences can be made to set to any desirable (small) constant value. Using only parameter based group ring calculations, we characterize all 2-valued and almost 2-valued (i.e., two-valued except for the first position which uses a third value) CAZAC and CASAC sequences. A one-parameter infinite family of CASAC we construct may have applications in Multiple-Input Multiple-Output (MIMO) areas. Toward this, we introduce a performance measure we term as cross merit factor to study cross correlation behavior, generalizing the celebrated notion of Golay Merit Factor (GMF).

Joint work with Michael R. Clark and Jeffrey R. Hollon.

Butson Hadamard full propelinear codes

I. Bailera

Department of Applied Mathematics, University of Zaragoza, Spain

In this talk we deal with Butson Hadamard matrices, and codes over finite rings coming from these matrices in logarithmic form, called BH-codes. We introduce a new morphism of Butson Hadamard matrices through a generalized Gray map on the matrices in logarithmic form, which is comparable to the morphism given in a recent note of Ó Catháin and Swartz. That is, we show how, if given a Butson Hadamard matrix over the k^{th} roots of unity, we can construct a larger Butson matrix over the l^{th} roots of unity for any l dividing k, provided that any prime p dividing k also divides l. We prove that a $\mathbb{Z}_{p^s}$-additive code with p a prime number is isomorphic as a group to a BH-code over $\mathbb{Z}_{p^s}$ and the image of this BH-code under the Gray map is a BH-code over $\mathbb{Z}_p$ (binary Hadamard code for $p = 2$). Further, we investigate the inherent propelinear structure of these codes (and their images) when the Butson matrix is cocyclic. Some structural properties of these codes are studied and examples are provided.

Joint work with J. A. Armario (U. de Sevilla, Spain) and R. Egan (NUI Galway, Ireland).

A construction of $\mathbb{Z}_4$-codes from generalized bent functions

Sara Ban

Department of Mathematics, University of Rijeka

A generalized Boolean function on n variables is a mapping $f : \mathbb{F}_2^n \to \mathbb{Z}_{2^h}$. The generalized Walsh-Hadamard transformation of f is $\tilde{f}(v) = \sum_{x \in \mathbb{F}_2^n} \omega^{f(x)}(-1)^{\langle v,x \rangle}$, where $\omega = e^{\frac{2\pi i}{2^h}}$. A generalized bent function (gbent function) is a generalized Boolean function f such that $|\tilde{f}(v)| = 2^{\frac{n}{2}}$, for every $v \in \mathbb{F}_2^n$. We consider generalized bent functions from $\mathbb{F}_2^n$ into $\mathbb{Z}_4$.

A Type IV-II $\mathbb{Z}_4$-code is a self-dual code over $\mathbb{Z}_4$ with the property that all Euclidean weights are divisible by eight and all codewords have even Hamming weight.

The subject of this talk is a construction of Type IV-II codes over $\mathbb{Z}_4$ from generalized bent functions.

We use generalized bent functions for a construction of self-orthogonal codes over $\mathbb{Z}_4$ of length 2^m, for m odd, $m \geq 3$, and prove that for $m \geq 5$ those codes can be extended to Type IV-II $\mathbb{Z}_4$-codes. From that family of Type IV-II $\mathbb{Z}_4$-codes, we construct a family of self-dual Type II binary codes by using the Gray map.

We consider the weight distributions of the obtained codes.

This is joint work with Sanja Rukavina.

Neumaier graphs

Maarten De Boeck

Eindhoven University of Technology

A *Neumaier graph* is an edge-regular graph with a regular clique. A lot of strongly regular graphs (but clearly not all of them) are indeed Neumaier, but in [1] it was asked whether there are Neumaier graphs that are not strongly regular. This question was only solved very recently (see [2]), so now we know there are so-called *strictly* Neumaier graphs.

In this talk I will discuss several new results on Neumaier graphs, including bounds and (non)-existence results. I will focus on a new construction producing lots of new strictly Neumaier graphs. This construction uses basic number theory, and raises some not-so basic number theory questions. I will also address some results abouth the eigenvalues of strictly Neumaier graphs.

This is joint work with Aida Abiad, Wouter Castryck, Bart De Bruyn, Jack Koolen and Sjanne Zeijlemaker

[1] A. Neumaier, Regular cliques in graphs and special 1 1/2-designs. 1981.

[2] G.R. Greaves and J.H. Koolen, Edge-regular graphs with regular cliques. European J. Combin., 71, 194–201, 2018.

Quantum Solution to the Problem of 36 Officers of Euler

Wojciech Bruzda

Institute of Theoretical Physics, Jagiellonian University, ul. Łojasiewicza 11, 30-348 Kraków, Poland

We present analytical solution to the quantum analogue of the famous problem of 36 officers of Euler. The result gives positive answer to several related questions concerning existence of two quantum orthogonal Latin squares of size six, Absolutely Maximally Entangled state AME(4, 6) for four parties with six levels each, $2-$unitary matrix of size 36 with maximal entangling power, perfect tensor T_{ijkl} with four indices each running from 1 to 6 or pure nonadditive quantum error correction code $((4, 1, 3))_6$.

This is the joint work with Suhail Ahmad Rather, Adam Burchardt, Grzegorz Rajchel-Mieldzioć, Arul Lakshminarayan and Karol Życzkowski.
Preprint is available online: `arXiv:2104.05122`.

On the spouse-loving variant of the Oberwolfach Problem

Andrea Burgess

University of New Brunswick

In the 1960s, Ringel posed the Oberwolfach Problem: at a conference with v attendees, the dining room has tables of sizes $n_1, n_2, \ldots, n_t$, where $n_1 + n_2 + \cdots + n_t = v$. Is it possible to find a seating plan over successive nights of the conference so that each person sits next to each other person exactly once?

In graph-theoretical terms, Ringel's problem asks for a 2-factorization of K_v in which each 2-factor is isomorphic to a given 2-factor $\mathcal{F}$. Such a factorization of the complete graph can exist only if v is odd. For even orders, it is common to study the maximum packing variant, in which we factor $K_v - I$, the complete graph with the edges of a 1-factor removed; this is sometimes referred to as the spouse-avoiding variant. In this talk, we consider the minimum covering version, which we nickname the spouse-loving variant. Here, given a 2-factor $\mathcal{F}$ of even order v, we seek an $\mathcal{F}$-factorization of $K_v + I$, the complete graph with the edges of a 1-factor duplicated. We discuss the problem in the cases that the 2-factor $\mathcal{F}$ is uniform or bipartite.

This talk includes joint work with Noah Bolohan, Iona Buchanan, Mateja Šajna and Ryan Van Snick.

Counting erasure patters of SPC product codes by means of bipartite graphs

Sara D. Cardell

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Universidade Federal do ABC (UFABC)
Brazil

The single parity-check (SPC) code is one of the most popular MDS error detection codes, since it is very easy to implement [1]. One bit is appended to an information sequence of length $n-1$, such that the resultant codeword has an even number of ones. Two or more SPC codes can be used jointly to obtain an SPC product code. This product code has 4 as minimum distance, then it can recover all erasure patterns with one, two, and three erasures. However, up to $2n-1$ erasures can be corrected in some special cases. Furthermore, a codeword of length n^2 can be represented by an erasure pattern of size $n \times n$, where the unique information considered is the position of the erasures. In [1], authors proposed an approach of the post-decoding erasure rate of the SPC product code. This process was based on observing the structure of the erasure patterns, classifying them into correctable or uncorrectable. In this work, we represent each erasure pattern by a binary matrix where there is a 1 in the position of the erasures. Then, the problem of counting patterns can be seen as a problem of counting binary matrices with some special properties. At the same time, we can represent each erasure pattern by a bipartite graph [2] with n nodes in each vertex class and the same number of edges as erasures. The binary matrix mentioned before is the bi-adjacency matrix of the bipartite graph. Then, the problem of counting uncorrectable erasure patterns can be seen as a problem of counting bipartite graphs with cycles. In [3], the author used Kostka number to count binary matrix with a fixed row and column sum. Here, we use the same idea to provide an expression that helps to count the number of bipartite graphs with cycles and, therefore, to count the number of strict uncorrectable erasure patterns.

Joint work with professor Joan-Josep Climent (Universitat d'Alacant, Spain).

[1] Kousa, M. A.: A novel approach for evaluating the performance of SPC product codes under erasure decoding. IEEE Transactions on Communications **50**(1), 7–11 (2002).

[2] R. Diestel, *Graph Theory*, Springer-Verlag, New York, NY, 2000.

[3] Brualdi, R. A.: Algorithms for constructing (0,1)-matrices with prescribed row and column sum vectors. Discrete Mathematics **306**(23), 3054–3062 (2006).

Speeding up Inference in Machine Learning Algorithms using Hadamard Matrices

Thomas Y. Chen

Academy for Mathematics, Science, and Engineering, Rockaway, NJ 07058, USA

Machine learning algorithms for classification tasks have a variety of use cases and applications. One model type, the artificial neural network, has become increasingly popularized over the last decades, with fascinating applications in computer vision and elsewhere. Such classifier algorithms have a number of parameters and yield a per-class value. In this work, we discuss the use of a Hadamard matrix to initialize the classifier, which in turn speeds up inference. The aforementioned matrix is position at the final classification transform, which yields two primary benefits. Firstly, it is a deterministic, low-memory, and easily generated matrix that can be used classify. Secondly, it is removes the need to perform matrix-matrix multiplication. By speeding up performance, we can enable further state-of-the-art results on many tasks that have immense applicability in the real world.

Generalizations of Heffter arrays and biembedding (multi)graphs on surfaces

Simone Costa

University of Brescia

In this talk, we present two classes of partially filled arrays that generalize the concept of Heffter array introduced by Archdeacon in 2015.

First of all, we introduce the relative Heffter arrays here denoted by $\mathrm{H}_t(m,n;s,k)$. A $\mathrm{H}_t(m,n;s,k)$ is an $m \times n$ partially filled array with elements in $\mathbb{Z}_v$, where $v = 2nk + t$, whose rows contain s filled cells and whose columns contain k filled cells, such that the elements in every row and column sum to zero and, for every $x \in \mathbb{Z}_v$ not belonging to the subgroup of order t, either x or $-x$ appears in the array. Then we present the more general class of λ-fold relative Heffter arrays denoted by ${}^{\lambda}\mathrm{H}_t(m,n;s,k)$. In this case $v = \frac{2nk}{\lambda} + t$ and, given an element $x \in \mathbb{Z}_v$ that does not belong to the subgroup of order t, the sum of the occurrences of x and $-x$ in the array is required to be λ.

Finally, we show that also these generalizations of the Heffter arrays, as well as the classical concept, can be used to construct 2-colourable embeddings (i.e. biembeddings) of cyclic cycle decompositions of complete multipartite (multi)graphs into orientable surfaces.

Joint work with Fiorenza Morini, Anita Pasotti and Marco Antonio Pellegrini.

Unit gain graphs with two distinct eigenvalues and systems of lines in complex space

Edwin R. van Dam

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Since the introduction of the Hermitian adjacency matrix for digraphs, interest in so-called complex unit gain graphs has surged. In this talk, we consider gain graphs with two distinct eigenvalues. Analogously to graphs with few distinct eigenvalues, a great deal of structural symmetry is required. This allows us to draw a parallel to well-studied systems of lines in complex space, through a natural correspondence to unit-norm tight frames. Examples are drawn from various relevant concepts related to lines in complex space with few angles, including SIC-POVMs and MUBs. Other examples relate to the hexacode, Coxeter-Todd lattice, and the Van Lint-Schrijver association scheme. Many other examples can be obtained as induced subgraphs by employing a technique parallel to the dismantling of association schemes. Specific examples thus arise from (partial) spreads in some small generalized quadrangles. Finally, we offer a full classification of two-eigenvalue gain graphs with degree at most 4, or with multiplicity at most 3.

Joint work with Pepijn Wissing.

Cycle Decompositions of Complete Digraphs

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We consider the problem of decomposing the complete directed graph K_n^* into directed cycles of given lengths. We consider general necessary conditions for a directed cycle decomposition of K_n^* into t cycles of lengths $m_1, m_2, \ldots, m_t$ to exist and provide a construction for creating such decompositions in the case where there is one 'large' cycle. We give a complete solution in the case when there are exactly three cycles of lengths $\alpha, \beta, \gamma \neq 2$. Somewhat surprisingly, the general necessary conditions turn out not to be sufficient in this case. In particular, taking $2 < \alpha \leq \beta \leq \gamma$, when $\gamma = n$, $\alpha + \beta > n + 2$ and $\alpha + \beta \equiv n \pmod 4$, K_n^* is not decomposable.

Joint work with Andrea Burgess and Tariq Javed.

On the Hadamard maximal determinant problem

Ronan Egan

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In a celebrated paper of 1893, Hadamard established the maximal determinant theorem, which establishes an upper bound on the determinant of a matrix with complex entries of norm at most 1. His paper concludes with the suggestion that mathematicians study the maximum value of the determinant of an $n \times n$ matrix with entries in $\{\pm 1\}$. This is the Hadamard maximal determinant problem.

It is known that an $n \times n$ matrix with entries in $\{\pm 1\}$ that attains Hadamard's upper bound exists only when n is equal to 1, 2, or a multiple of 4. Such a matrix is now commonly known as a Hadamard matrix, and these have been well studied. Less well known, is the state of play where $n > 4$ and $n \not\equiv 0 \mod 4$. In this talk I will survey the progress on the Hadamard maximal determinant problem for $n \not\equiv 0 \mod 4$.

This is joint work with Patrick Browne, Fintan Hegarty, and Pádraig Ó Catháin.

On the fractal dimension of strongly isotopism classes of Latin squares

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Based on an iterative construction of pseudo-random sequences, Dimitrova and Markovski [1] described a graphical representation of quasigroups by means of image patterns with a certain fractal character. It is so that one may distinguish among fractal and non-fractal quasigroups. In the literature, the former are recommended for designing error detecting codes, whereas the second ones play a relevant role for designing cryptographic primitives. Furthermore, the analysis and recognition of these fractal image patterns have recently turned out to be an efficient way to distinguish isomorphism classes of non-idempotent Latin squares [2, 3]. This talk delves into this topic by introducing the concept of (s,t)-standard set of image patterns associated to a quasigroup. The mean fractal dimension of these standard sets constitutes a new strongly isotopism invariant, which enables one to characterize in an efficient way distinct strongly isotopism classes of Latin squares, even if they are idempotent.

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[2] R. M. Falcón, *Recognition and analysis of image patterns based on Latin squares by means of Computational Algebraic Geometry*, Mathematics **9** (2021), paper 666, 26 pp.

[3] R. M. Falcón, V. Álvarez, F. Gudiel, *A Computational Algebraic Geometry approach to analyze pseudo-random sequences based on Latin squares*, Adv. Comput. Math. **45** (2019), 1769–1792.

On some constructions of LCD codes

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Linear codes with complementary duals, shortly named LCD codes, are linear codes whose intersection with their duals is trivial. In this talk, we present a construction for LCD codes over finite fields from the adjacency matrices of two-class association schemes. These schemes consist of either strongly regular graphs (SRGs) or doubly regular tournaments (DRTs).

Joint work with Dean Crnković and Andrea Švob.

Entanglement of free Fermions on distance-regular graphs

Krystal Guo

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Many physical processes evolving over time on an underlying graph have led to problems in spectral graph theory, including quantum walks. These problems provide new graph invariants and also new applications for theorems about the eigenspaces of graphs. In this talk, we will consider free fermions on vertices of distance-regular graphs are considered. Using concepts from Terwilliger algebras, we study the entanglement Hamiltonian. This is based on joint work with

Joint work with Nicolas Crampé and Luc Vinet.

Neighbour-transitive codes in generalised quadrangles

Daniel Hawtin

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A code C in an arbitrary graph Γ is a subset of the vertex set of Γ. The minimum distance δ of a code C is the smallest distance between a pair of distinct elements of C and the graph metric gives rise to the distance partition $\{C, C_1, \ldots, C_\rho\}$, where ρ is the maximum distance between any vertex of Γ and its nearest element in C. In this talk we consider the case where Γ is the point-line incidence graph of a generalised quadrangle $\mathcal{Q}$ and we say that C is a code in the generalised quadrangle $\mathcal{Q}$. Since the diameter of Γ is 4, both ρ and δ are at most 4. If $\delta = 4$ then C is a partial ovoid or partial spread of $\mathcal{Q}$, and if, additionally, $\rho = 2$ then C is an ovoid or a spread. A code C in $\mathcal{Q}$ is neighbour-transitive if its automorphism group acts transitively on each of the sets C and C_1. Our main results i) classify all neighbour-transitive codes admitting an insoluble group of automorphisms in thick classical generalised quadrangles that correspond to ovoids or spreads, and ii) give two infinite families and six sporadic examples of neighbour-transitive codes with minimum distance $\delta = 4$ in the classical generalised quadrangle $\mathsf{W}_3(q)$ that are not ovoids or spreads.

Joint work with Dean Crnković and Andrea Švob.

A Markov chain on the solution space of edge-colorings of bipartite graphs

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The Latin squares L_n are $n \times n$ grids such that each row and column consist of numbers 1 to n. It is a family of important combinatorial objects but with no known easily computable formula for its quantity. A Latin rectangle is an $(n-k) \times n$ grid with each row consisting 1 to n and each column has no repeat. One may see that there is a natural bijection between all possible Latin square completions of Latin rectangles and the proper edge k-colorings of a regular equi-bipartite graph.

Counting and sampling are related problems. Motivated by the above, we exhibit an irreducible Markov chain M on the edge k-colorings of bipartite graphs based on certain properties of the solution space. We show that diameter of this Markov chain grows linearly with the number of edges in the graph. We also prove a polynomial upper bound on the inverse of acceptance ratio of the Metropolis-Hastings algorithm when the algorithm is applied on M with the uniform distribution of all possible edge k-colorings of G.

Joint work with István Miklós, Alfréd Rényi Institute of Mathematics.

[1] L. Hong and I. Miklos. *A Markov chain on the solution space of edge-colorings of bipartite graphs*. Submitted. https://arxiv.org/abs/2103.11990

Constructions of new matroids and designs over $\mathbb{F}_q$

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A *perfect matroid design (PMD)* is a matroid whose flats of the same rank all have the same size. As the name suggest, these matroids give rise to certain designs, and in the literature this construction is used to find new designs. The aim of this work is to establish a q-analogue of this construction.

We will introduce the q-analogue of a PMD and its properties. In order to do that, we first define a q-matroid in terms of its flats. We show that q-Steiner systems are examples of q-PMD's, just like Steiner systems are examples of PMD's. We use the q-matroid structure to construct subspace designs from q-Steiner systems. We apply this construction to known q-Steiner systems and discuss the designs coming from it.

This talk is based on joint work with Eimear Byrne, Michela Ceria, Sorina Ionica and Elif Saçikara.

Constructions of divisible design Cayley graphs

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A k-regular graph on v vertices is a *divisible design graph* with parameters $(v, k, \lambda_1, \lambda_2, m, n)$ if the vertex set can be partitioned into m classes of size n, such that two distinct vertices from the same class have exactly λ_1 common neighbours, and two vertices from different classes have exactly λ_2 common neighbours [1, 3]. This partition into classes is called a *canonical partition.*

Divisible design graphs are a special case of Deza graphs. A *Deza graph* with parameters (v, k, b, a) is a k-regular graph on v vertices in which the number of common neighbours of two distinct vertices takes exactly two values a or b, where $a \leq b$. Deza graphs were introduced in [2]. Deza graphs generalise strongly regular graphs since the number of common neighbours are independent of vertex adjacency.

Let G be a finite group and S be a subset of G which does not contain the identity element and is closed under inversion. The Cayley graph $\mathrm{Cay}(G, S)$ is a graph with the vertex set G in which two vertices x, y are adjacent if and only if $xy^{-1} \in S$. The following theorem gives necessary and sufficient conditions for a Deza Cayley graph to be a divisible design Cayley graph.

Theorem. *Let* $\mathrm{Cay}(G, S)$ *be a Deza graph with parameters* (v, k, b, a)*. Let* A*,* B *and* $\{e\}$ *be a partition of* G *and* SS^{-1} *be a multiset such that* $SS^{-1} = aA + bB + k\{e\}$*. If either* $A \cup \{e\}$ *or* $B \cup \{e\}$ *is a subgroup of* G*, then* $\mathrm{Cay}(G, S)$ *is a divisible design graph and the right cosets of this subgroup give a canonical partition of the graph. Conversely, if* $\mathrm{Cay}(G, S)$ *is a divisible design graph, then the class of its canonical partition which contains the identity of* G *is a subgroup of* G *and classes of the canonical partition of the divisible design graph coincide with the cosets of this subgroup.*

This Theorem shows that Cayley divisible design graphs arise only by means of divisible difference sets relative to some subgroup. Using divisible difference sets relative to some subgroup we present new constructions of divisible design graphs. This is joint work with Leonid Salaginov.

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On α-points of q-analogs of the Fano plane

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Arguably, the most important open problem in the theory of q-analogs of designs is the question for the existence of a q-analog D of the Fano plane. It is undecided for every single prime power value $q \geq 2$.

A point P is called an α-point of D if the derived design of D in P is a geometric spread. In 1996, Simon Thomas has shown that there must always exist at least one non-α-point. For the binary case $q = 2$, Olof Heden and Papa Sissokho have improved this result in 2016 by showing that the non-α-points must form a blocking set with respect to the hyperplanes.

We will show that a hyperplane consisting only of α-points implies the existence of a partiton of the symplectic generalized quadrangle $W(q)$ into spreads. As a consequence, the statement of Heden and Sissokho is generalized to all primes q and all even values of q.

On 4-designs with three intersection numbers

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A t-(v, k, λ) design with two block intersection numbers is called *quasi-symmetric*. For such designs, it is known that $t \leq 4$ holds [2] and the only examples with $t = 4$ are the derived Witt design 4-$(23, 7, 1)$ and its complement [1, 4]. Regarding designs with three block intersection numbers, $t \leq 5$ holds and the only examples with $t = 5$ are hypothesized to be the Witt design 5-$(24, 8, 1)$ and its complement [5].

We will report on 4-designs with three intersection numbers and present a table of small admissible parameters. By the Cameron-Delsarte theorem [2, 3], such designs must be schematic, meaning that the blocks form a symmetric association scheme. This imposes strong restrictions on the parameters. However, in this case there are small examples not related to the Witt design, e.g. a 4-$(47, 11, 8)$ design constructed by Tonchev [6].

This is joint work with Renata Vlahović Kruc.

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Extending perfect matchings to Hamiltonian cycles in line graphs

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A graph admitting a perfect matching has the Perfect-Matching-Hamiltonian property (for short the PMH-property) if each of its perfect matchings can be extended to a Hamiltonian cycle. In this talk we will present some sufficient conditions for a graph G which guarantee that its line graph $L(G)$ has the PMH-property. In particular, we prove that this happens when G is (i) a Hamiltonian graph with maximum degree at most 3, (ii) a complete graph, or (iii) an arbitrarily traceable graph. Further related questions and open problems will be stated.

Joint work with M. Abreu, John Baptist Gauci, Giuseppe Mazzuoccolo and Jean Paul Zerafa.

Intersection Distribution and Its Application

Shuxing Li

Simon Fraser University

Given a polynomial f over finite field $\mathbb{F}_q$, its intersection distribution concerns the collective behaviour of a series of polynomials $\{f(x) + cx | c \in \mathbb{F}_q\}$. Each polynomial f canonically induces a $(q+1)$-set S_f in the classical projective plane $PG(2, q)$ and the intersection distribution of f reflects how the point set S_f interacts with the lines in $PG(2, q)$.

Motivated by the long-standing open problem of classifying oval monomials, which are monomials over $\mathbb{F}_{2^m}$ having the same intersection distribution as x^2, we consider the next simplest case: classifying monomials over $\mathbb{F}_q$ having the same intersection distribution as x^3. Some characterizations of such monomials are derived and consequently a conjectured complete list is proposed.

Among the conjectured list, we identify two exceptional families of monomials over $\mathbb{F}_{3^m}$. Interestingly, new examples of Steiner triple systems follow from them, which are nonisomorphic to the classical ones.

This is joint work with Gohar Kyureghyan and Alexander Pott.

Cameron-Liebler line classes in AG$(3, q)$

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Cameron-Liebler (CL) line classes were first observed by Cameron and Liebler to classify certain subgroup structures in PG$(3, q)$. A CL line class $\mathcal{L}$ is characterized by the property that for every line spread $\mathcal{S}$ it holds that $|\mathcal{L} \cap \mathcal{S}| = x$. This fixed number $x \in \mathbb{N}$ is called the *parameter* of $\mathcal{L}$. The goal of this talk is to consider CL line classes $\mathcal{L}$ and its properties in AG$(3, q)$, see [2], with a similar definition as in PG$(3, q)$. Because AG$(3, q)$ has significantly more line spreads then PG$(3, q)$, a CL line class in AG$(3, q)$ is actually a special type of CL line class in PG$(3, q)$. This will induce the inherence of many properties for CL line classes in PG$(3, q)$. One of these properties is a non-existence condition based on the modular equality obtained in [4], which allows us to calculate an upper bound on the possible parameters x of a CL line class in AG$(3, q)$. A second important consequence is the existence of a CL line class of parameter $x = \frac{q^2-1}{2}$ in AG$(3, q)$, for $q \equiv 5$ or 9 mod 12. This example will be based on the example found in [1] and [3]. These results will imply a classification of the parameters of a Cameron-Liebler line class in AG$(3, q)$, $q \leq 5$.

Joint work with Jozefien D'haeseleer, Leo Storme and Andrea Švob.

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Eigenvalues of oppositeness graphs and Erdős-Ko-Rado for flags

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Over the last few years, Erdős-Ko-Rado theorems have been found in many different geometrical contexts including for example sets of subspaces in projective or polar spaces. A recurring theme throughout these theorems is that one can find sharp upper bounds by applying the Delsarte-Hoffman coclique bound to a matrix belonging to the relevant association scheme. In the aforementioned cases, the association schemes turn out to be commutative, greatly simplifying the matter. However, when we do not consider subspaces of a certain dimension but more general flags, we lose this property. In this talk, we will explain how to overcome this problem, using a result originally due to Brouwer. This result, which has seemingly been flying under the radar so far, allows us to find eigenvalues of oppositeness graphs and derive sharp upper bounds for EKR-sets of certain flags in projective spaces and general flags in polar spaces and exceptional geometries. We will show how Chevalley groups, buildings, Iwahori-Hecke algebras and representation theory tie into this story and discuss their connections to the theory of non-commutative association schemes.

Joint work with Jan De Beule and Klaus Metsch.

Completely regular codes in Johnson and Grassmann graphs with small covering radii

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Let C be a code (a collection of vertices) in a regular graph Γ. A vertex x is in C_i if the minimum of the distances between x and the vertices of C is i. The maximum of these distances is called *the covering radius* of C and is denoted by ρ. A code C is called *completely regular* if there are numbers $\alpha_0, \dots, \alpha_\rho$, $\beta_0, \dots, \beta_{\rho-1}$, $\gamma_1, \dots, \gamma_\rho$ such that for every $i \in \{0, \dots, \rho\}$ any vertex of C_i is adjacent to exactly α_i, β_i and γ_i vertices of C_{i-1}, C_i and C_{i+1} respectively.

Let $\mathcal{L}$ be a 2-spread in $PG(n-1, q)$ (i.e. $1-(n, 2, 1)_q$–design). This code is known to be completely regular in the Grassmann graph $J_q(n, 2)$ [1,Corollary 3.5] with covering radius 1. For fixed $k, k \geq 3$ consider the code D of k-subspaces, which do not contain subspaces from $\mathcal{L}$. When k is 3 this code is completely regular in $J_q(n, 3)$ [2]. Our result is that if k is 4 and $\mathcal{L}$ is a Desarguesian spread then the code D is completely regular in $J_q(n, 4)$ with covering radius 2. In a similar manner we construct a completely regular code in the Johnson graph $J(n, 6)$ from the affine Steiner quadruple system of order $n = 2^m$. We also obtain several new completely regular codes with covering radius 1 in the Grassmann graph $J_2(6, 3)$ using binary linear programming. A detailed description of these results with proofs could be found in [3].

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On flag-transitive symmetric 2-(v, k, λ) designs

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In literature there are many papers devoted to the study of symmetric 2-(v, k, λ) designs $\mathcal{D} = (\mathcal{P}, \mathcal{B})$ admitting a flag-transitive automorphism group G. If $\lambda = 1$, then G acts point-primitively on $\mathcal{D}$, and both $\mathcal{D}$ and G are essentially classified by Kantor (1985). The case $\lambda > 1$ is different: it is far from being settled and there are several examples of 2-designs admitting a flag-transitive, point-imprimitive automorphism group. In the latter case, if G acts point-primitively on $\mathcal{D}$, remarkable results were obtained by O'Reilly-Reguerio (2005) for $\lambda = 2$, Zhou et al. (2010) for $\lambda = 3, 4$, by Braić et al. (2011) for $v < 2500$, by Biliotti and Montinaro (2016) and by Alavi, Zhou et al. (2021) for $gcd(k, v) = 1$. If G acts point-imprimitively on $\mathcal{D}$, then Praeger and Zhou (2006) have shown that each line of $\mathcal{D}$ intersects any block of imprimitivity either in 0 or in a constant number x of points, $x \geq 2$. Moreover, either $k \leq \lambda(\lambda - 3)/2$ or the parameters of $\mathcal{D}$ are determined as a function of λ.

The aim of this talk is to provide an approach to determine $\mathcal{D}$ for $k > \lambda(\lambda - 3)/2$ and $x > 2$. More precisely we show that, for $x > 2$ the incidence structure $\mathcal{D}_0 = (\mathcal{P}_0, \mathcal{B}_0)$, where $\mathcal{P}_0$ is a block of imprimitivity for G on $\mathcal{P}$ and $\mathcal{B}_0 = \{\mathcal{P}_0 \cap \ell \neq \varnothing : \ell \in \mathcal{B}\}$, is a 2-design admitting $G_{\mathcal{P}_0}^{\mathcal{P}_0}$ as a flag-transitive automorphism group. Also, the group $G_{\mathcal{P}_0}^{\mathcal{P}_0}$ acts point-primitively on $\mathcal{D}$ for $k > \lambda(\lambda - 3)/2$. This allows to classify $\mathcal{D}_0$ and hence to determine strong constraints for the structure of $\mathcal{D}$.

Distance-regular graphs from the Mathieu groups

Nina Mostarac

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In this talk we will describe a construction of distance-regular graphs admitting a transitive action of the five Mathieu groups M_{11}, M_{12}, M_{22}, M_{23} and M_{24}. We will also discuss a possibility of permutation decoding of the codes spanned by the adjacency matrices of the graphs constructed and find small PD-sets for some of the codes.

Joint work with Dean Crnković and Andrea Švob.

On extremal self-dual $\mathbb{Z}_4$-codes

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A linear $\mathbb{Z}_4$-code C of length n is a $\mathbb{Z}_4$ sub-module of $\mathbb{Z}_4^n$. With respect to the standard inner product modulo 4, the dual code $C^\perp$ of the $\mathbb{Z}_4$-code C is defined. The code C is self-dual if $C \subseteq C^\perp$. There are two binary codes associated with a $\mathbb{Z}_4$-code C called a residue code and a torsion code. These two codes are a starting point in the construction of self-dual $\mathbb{Z}_4$-codes by the method given in [1]. For $\mathbb{Z}_4$-codes the Euclidean weight of codeword x is defined by $n_1(x)+4n_2(x)+n_3(x)$, where $n_i(x)$ is the number of components of x which are equal to i. A $\mathbb{Z}_4$-code C of length n is said to be extremal if its minimal Euclidean weight is $8\lfloor \frac{n}{24} \rfloor + 8$. In this talk, we will discuss an algorithm that improves the search for extremal self-dual $\mathbb{Z}_4$-codes which we used to obtain some new extremal codes.

This is joint work with Sanja Rukavina.

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A Combinatorial Approach to Flag Codes

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In network coding, a flag code is a collection of sequences of nested subspaces of $\mathbb{F}_q^n$, being $\mathbb{F}_q$ the finite field with q elements. This family of codes was first introduced in [**?**]. Even though flag codes can be seen as a generalization of subspace codes, their distance is a much more complex parameter than the subspace distance. In this talk we present a combinatorial approach to flag codes by means of which we can interpret the possible realizations of a flag code distance value as different partitions of an appropriate integer. This viewpoint allows us to extract information about the flag code in terms of well-know concepts coming from the classical theory of partitions.

Joint work with Clementa Alonso-Gonzlez.

A family of non-Cayley cores that is constructed from vertex-transitive or strongly regular self-complementary graphs

Marko Orel

University of Primorska & IMFM

Let Γ be a finite simple graph on n vertices. In the talk I will consider the graph $\Gamma \equiv \bar{\Gamma}$ on $2n$ vertices, which is obtained as the disjoint union of Γ and its complement $\bar{\Gamma}$, where we add a perfect matching such that each its edge joins two copies of the same vertex in Γ and $\bar{\Gamma}$. The graph $\Gamma \equiv \bar{\Gamma}$ generalizes the Petersen graph, which is obtained if Γ is the pentagon. It is a non-Cayley graph if $n > 1$, and is vertex-transitive if and only if Γ is vertex-transitive and self-complementary. In this case $\Gamma \equiv \bar{\Gamma}$ is Hamiltonian-connected whenever $n > 5$. It is shown that the fraction between the cardinalities of the automorphism groups of $\Gamma \equiv \bar{\Gamma}$ and Γ can attain only values 1, 2, 4, or 12, and the corresponding four classes of graphs are described. The spectrum of the adjacency matrix of $\Gamma \equiv \bar{\Gamma}$ is computed whenever Γ is regular. The main results involve the endomorphisms of $\Gamma \equiv \bar{\Gamma}$. It is shown that the graph $\Gamma \equiv \bar{\Gamma}$ is a core, i.e. all its endomorphisms are automorphisms, whenever Γ is strongly regular and self-complementary. The same result is obtained for many cases, where Γ is vertex-transitive and self-complementary.

Small complete caps in $PG(4n+1,q)$

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Let $PG(r,q)$ denote the r-dimensional projective space over the finite field with q elements F_q. A *k-cap* of $PG(r,q)$ is a set of k points no three of which are collinear. A k-cap of $PG(r,q)$ is said to be *complete* if it is not contained in a $(k+1)$-cap of $PG(r,q)$. The study of caps is not only of geometrical interest, but arises from coding theory. Indeed, by identifying the representatives of the points of a complete k-cap of $PG(r,q)$ with columns of a parity check matrix of a q–ary linear code, it follows that (apart from three sporadic exceptions) complete k-caps of $PG(r,q)$ with $k > r+1$ and non-extendable linear $[k, k-r-1, 4]_q$ 2–codes are equivalent objects.

One of the main issue is to determine the spectrum of the sizes of complete caps in a given projective space and in particular their maximal and minimal possible values. For the size $t_2(r,q)$ of the smallest complete cap in $PG(r,q)$, the trivial lower bound is $t_2(r,q) > \sqrt{2}q^{\frac{r-1}{2}}$. Apart from the cases q even and r odd, all known infinite families of complete caps explicitly constructed in $PG(r,q)$ have size far from the trivial bound.

In this talk I will describe the construction of a complete cap of $PG(4n+1,q)$ of size $2(q^{2n}+\cdots+1)$ that is obtained by projecting two disjoint Veronese varieties of $PG(n(2n+3),q)$ from a suitable $(2n^2-n-2)$-dimensional projective space. This establishes that the trivial lower bound on $t_2(4n+1,q)$ is essentially sharp.

This is joint work with A. Cossidente, B. Csajbók and G. Marino.

Perfect 1-Factorisations

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A matching in a graph G is a subset $M \subseteq E(G)$ of the edge set of G such that no two edges of M share a vertex. A 1-factor of a graph G is a matching F in which every vertex of G is in one of the edges of F. If G is a Δ-regular graph of even order then we can ask whether G admits a 1-factorisation, namely a partition of its edge set into Δ 1-factors.

Suppose that $F_1, F_2, \ldots, F_\Delta$ are the 1-factors of a 1-factorisation $\mathcal{F}$ of a Δ-regular graph G. If, for each $1 \leq i < j \leq \Delta$, the union $F_i \cup F_j$ is the edge set of a Hamilton cycle in G, then we say that $\mathcal{F}$ is a perfect 1-factorisation of G. We will discuss some of the history and properties of 1-factorisations, including the recent discovery of a perfect 1-factorisation of K_{56}.

New methods to attack the Buratti-Horak-Rosa conjecture

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The conjecture, still widely open, posed by Marco Buratti, Peter Horak and Alex Rosa states that a list L of $v-1$ positive integers not exceeding $\lfloor \frac{v}{2} \rfloor$ is the list of edge-lengths of a suitable Hamiltonian path of the complete graph with vertex-set $\{0, 1, \ldots, v-1\}$ if and only if, for every divisor d of v, the number of multiples of d appearing in L is at most $v-d$. We present new methods that are based on linear realizations that can be applied to prove the validity of this conjecture for a vast choice of lists. As example of their flexibility, we consider lists whose underlying set is one of the following: $\{x, y, x+y\}$, $\{1, 2, 3, 4\}$, $\{1, 2, 4, \ldots, 2x\}$, $\{1, 2, 4, \ldots, 2x, 2x+1\}$. We also consider lists with many consecutive elements.

Joint work with Matt Ollis (Emerson College, MA), Anita Pasotti (Università degli Studi di Brescia, Italy), and Marco Pellegrini (Università Cattolica del Sacro Cuore, Italy).

Bounds on permutation designs

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A notion of t-designs in the symmetric group on n letters was introduced by Godsil in 1988. In particular t-transitive sets of permutations are t-designs. We derive special lower bounds for $t = 1$ and $t = 2$ by a power moment method. For general n, t we give a a lower bound on the size of such t-designs of $n(n-1)\dots(n-t+1)$, which is best possible when sharply t-transitive sets of permutations exist. This shows, in particular, that tight 2-designs do not exist.

Joint work with Minjia Shi, and Xiaoxiao Li.

Reed – Muller like codes and their intersections

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The classical binary *Reed – Muller code of order* r, $0 \leq r \leq m$, for any $m \geq 1$ is defined as the set of all vectors of length 2^m corresponding to the boolean functions of m variables of degree not more than r. The Reed – Muller code is linear and has the following parameters: the length n of the code is 2^m, the size $2^k, k = \sum_{i=0}^{r} \binom{m}{i}$ and the *code distance* (the minimum value of the Hamming distance between any two different codewords from the code) is 2^{m-r}.

The code is called *self-complementary* if for any codeword x the code contains the vector $x + \mathbf{1}^n$, where $\mathbf{1}^n$ is the all-one vector of length n. The Reed – Muller code is self-complementary. A binary self-complementary code with the parameters of the classical Reed – Muller code is called a *Reed – Muller like code*. Such code is not necessarily linear. The class of the Reed – Muller like codes contains a rich families of codes obtained in [1]–[3].

We prove that there exist two Reed – Muller like codes of order r of length 2^m with the intersection number equaled $2\eta_1\eta_2$, where $1 \leq \eta_s \leq |RM(r-1, m-1)|$, $s \in \{1, 2\}$ for any admissible length beginning with 16. The result generalizes the result [4] concerning the intersection problem for perfect binary codes.

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Restrictions on parameters of partial difference sets in nonabelian groups

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A partial difference set S in a finite group G satisfying $1 \notin S$ and $S = S^{-1}$ corresponds to an undirected strongly regular Cayley graph $\mathrm{Cay}(G, S)$. While the case when G is abelian has been thoroughly studied, there are comparatively few results when G is nonabelian. We provide restrictions on the parameters of a partial difference set that apply to both abelian and nonabelian groups and are especially effective in groups with a nontrivial center. In particular, these results apply to p-groups, and we are able to rule out the existence of partial difference sets in many instances.

This is joint work with Gabrielle Tauscheck.

Marina Šimac

On some LDPC codes

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Low-density parity-check (LDPC) codes are a class of linear block codes that were first presented by Gallager in 1962. These codes have been the subject of much interest due to the fact that they can perform near Shannon limit. In this talk we study low-density parity-check (LDPC) codes having cubic semisymmetric graphs as their Tanner graphs. We will discuss some of the properties of the constructed codes and present bounds for the code parameters: code length, dimension and minimum distance. Moreover, information on the constructed codes, such as computational and simulation results, will be presented.

Joint work with Dean Crnković and Sanja Rukavina.

On Automorphisms of a binary Fano plane

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The existence of a binary q-analog of a Fano plane is still unknown. Kiermaier, Kurz and Wassermann proved that it's automorphism group is almost trivial. Namely, it contains at most two elements. The method used there involved Kramer - Masner method together with an extensive computer search. In this talk we provide an algebraic (computer free) proof that automorphisms of certain order can't do action on a binary q-analog of a Fano plane.

On abelian distance-regular covers of complete graphs related to rank 3 permutation groups

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A distance-regular antipodal cover of the complete graph K_n is equivalently defined as a connected graph, whose vertex set admits a partition into n (antipodal) classes of the same size $r \geq 2$ such that each class induces an r-coclique, the union of any two distinct classes induces a perfect matching, and any two non-adjacent vertices that lie in distinct classes have exactly $\mu \geq 1$ common neighbours; such a graph is briefly referred to as an (n, r, μ)-cover. An (n, r, μ)-cover is called *abelian* if the group of all its automorphisms fixing (setwise) every its antipodal class is abelian and acts regularly on every antipodal class of the cover. The study of abelian (n, r, μ)-covers is motivated by their various applications, e.g. in coding theory and discrete geometry. The aim of this talk is to investigate abelian (n, r, μ)-covers Γ with the following property: *there is a vertex-transitive group of automorphisms G of Γ which induces an almost simple primitive permutation group G^{Σ} on the set Σ of antipodal classes of Γ.* Such covers have been classified in the case when the permutation rank $\mathrm{rk}(G^{\Sigma})$ of G^{Σ} equals 2. We will present some recent results on classification of such covers in the case $\mathrm{rk}(G^{\Sigma}) = 3$.

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Quasi-symmetric 2-$(28, 12, 11)$ designs with an automorphism of order 5

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A t-(v, k, λ) design is *quasi-symmetric* if any two blocks intersect in either x or y points, for non-negative integers $x < y$. The first known quasi-symmetric 2-$(28, 12, 11)$ designs with intersection numbers $x = 4$ and $y = 6$ were constructed as derived designs of the symplectic symmetric 2-$(64, 28, 12)$ design [3]. There are four non-isomorphic SDP designs (designs with the symmetric difference property) with parameters 2-$(64, 28, 12)$. Derived designs any of them are quasi-symmetric 2-$(64, 28, 12)$ designs [2]. In [1], designs with these parameters were classified with an automorphism of order 7 without fixed points and blocks; there are exactly 246 such designs. Furthermore, in [4] the number of quasi-symmetric 2-$(28, 12, 11)$ designs was increased to 58 891.

Using a method based on tactical decompositions, we classified quasi-symmetric 2-$(28, 12, 11)$ designs with an automorphism of order 5. Up to isomorphism, there are exactly 31 696 such designs.

This is joint work with Vedran Krčadinac.

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A Hermitian adjacency matrix for Signed Directed Graphs

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The field of signed directed graphs, which is a natural marriage of the well-known fields concerning signed graphs and directed graphs, has thus far received little attention. To characterize such signed directed graphs, we formulate a Hermitian adjacency matrix, whose entries are the unit Eisenstein integers $\exp(k\pi i/3)$, $k \in \mathbb{Z}_6$.

Our main interest is spectral characterization. To this end, we provide a full classification of all signed digraphs with rank at most 3, and an extensive review of signed digraphs with at most 2 non-negative eigenvalues. We show that non-empty signed directed graphs whose spectra occur uniquely, up to isomorphism, do not exist, but we use the provided classification to provide several infinite families whose spectra occur uniquely up to (diagonal) switching equivalence.

Based on joint work with Edwin van Dam.

On the non-existence of srg(85,14,3,2) and the Euclidean representation

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In general, it is still an open question to determine whether a strongly regular graph with given parameters exists. In this talk I will introduce our approach proving the non-existence of srg(85,14,3,2): how we treat a strongly regular graph as a distance regular graph and its corresponding association scheme, how the Euclidean representation of a graph works, and our current progress on this problem.

This is a joint work with Professor Sergey Shpectorov.

$S(2,5,45)$ designs constructed from orbit matrices using a modified genetic algorithm

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Genetic algorithms (GA) are search and optimization heuristic population-based methods which are inspired by the natural evolution process. In this talk, we will present a method of constructing incidence matrices of block designs combining the method of construction with orbit matrices and a modified genetic algorithm. With this method we managed to find some new non-isomorphic S(2,5,45) designs.

Joint work with Dean Crnković.

The geometric counterpart of maximum rank metric codes

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The set of $m \times n$ matrices $\mathbb{F}_q^{m\times n}$ over $\mathbb{F}_q$ is a metric space with rank metric distance defined by $d(A,B) = \mathrm{rk}(A-B)$ for $A,B \in \mathbb{F}_q^{m\times n}$. A subset $\mathcal{C} \subseteq \mathbb{F}_q^{m\times n}$ is called *rank metric code*. The *minimum distance* of $\mathcal{C}$ is defined as

$$d(C) = \min_{A,B\in\mathcal{C},\ A\neq B}\{d(A,B)\}.$$

When $\mathcal{C}$ is an $\mathbb{F}_q$-linear subspace of $\mathbb{F}_q^{m\times n}$, we say that $\mathcal{C}$ is an $\mathbb{F}_q$-*linear rank metric code* and the *dimension* $\dim_q(\mathcal{C})$ is defined to be the dimension of $\mathcal{C}$ as a subspace over $\mathbb{F}_q$.

The Singleton bound for an $m \times n$ rank metric code $\mathcal{C}$ with minimum rank distance d, proved by P. Delsarte in [3] and by E. Gabidulin in [4], is

$$\#\mathcal{C} \leq q^{\max\{m,n\}(\min\{m,n\}-d+1)}.$$

If this bound is achieved, then $\mathcal{C}$ is called an *MRD-code*. Such codes have received great attention in recent years for their applications in cryptography and coding theory.

J. Sheekey in [6] opened a new perspective in the theory of MRD-codes: he proved that scattered $\mathbb{F}_q$-linear sets of $\mathrm{PG}(1,q^n)$ of maximum rank n yield $\mathbb{F}_q$–linear MRD-codes with dimension $2n$ and minimum distance $n-1$.

More generally, a linear set can be defined as follows. Let $V = V(r,q^n)$, $\Lambda = \mathrm{PG}(V,\mathbb{F}_{q^n}) = \mathrm{PG}(r-1,q^n)$, $q = p^h$ for some prime p. A pointset L of Λ is an $\mathbb{F}_q$-*linear set* of Λ of rank k if L consists of the points defined by the vectors of an $\mathbb{F}_q$-subspace U of V of dimension k, i.e.

$$L = L_U = \{\langle \mathbf{u}\rangle_{\mathbb{F}_{q^n}} : \mathbf{u} \in U \setminus \{\mathbf{0}\}\}.$$

For the number of points of an $\mathbb{F}_q$-linear set of rank k the following bound holds

$$|L_U| \leq \frac{q^k-1}{q-1},$$

and the $\mathbb{F}_q$-linear sets achieving this bound are called *scattered*, see [1]. Equivalently, it is possible to define scattered linear sets through the definition of the weight of a point. Let $\Omega = \mathrm{PG}(W,\mathbb{F}_{q^n})$ be a subspace of Λ and let L_U be an $\mathbb{F}_q$-linear set of Λ, then if $\dim_{\mathbb{F}_q}(W\cap U) = i$, we say that Ω has *weight* i in L_U, and we write $w_{L_U}(\Lambda) = i$. Hence, a scattered $\mathbb{F}_q$-linear set can be defined as an $\mathbb{F}_q$-linear set with the property that all of its points have weight one. In [2] the scattered property has been generalized by replacing points with subspaces of fixed dimension. More precisely, the $\mathbb{F}_q$-linear sets of Λ with the property that

$$w_{L_U}(\Omega) \leq h$$

for each $(h-1)$-subspace Ω of Λ and $\langle L_U \rangle_{\mathbb{F}_{q^n}} = \Lambda$ are called *h-scattered $\mathbb{F}_q$-linear sets*. It turns out that h-scattered $\mathbb{F}_q$-linear sets are scattered linear sets. Also, 1-scattered $\mathbb{F}_q$-linear sets coincide with the classical scattered linear sets generating the whole space defined above. The case $h = r - 1$ was also considered in [5, 7]. In [2] it was proved that for any h the rank of a h-scattered $\mathbb{F}_q$-linear set is bounded by $rn/(h+1)$ and examples of h-scattered linear sets whose rank attain this bound were given.

In this talk we will give a gentle introduction to the theory of h-scattered linear sets and we will deal with their connection with MRD-codes, extending the connection established in [6].

Joint work with Bence Csajbók, Giuseppe Marino, Vito Napolitano, Olga Polverino and Giovanni Zini.

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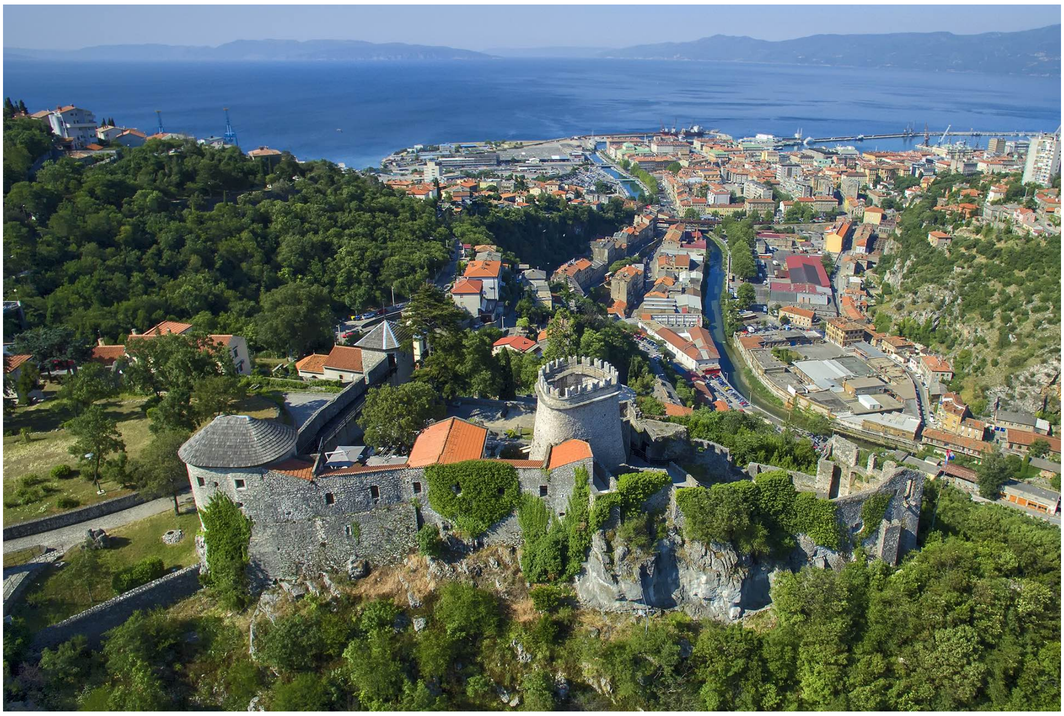
153. M. Villanueva, Universitat Autònoma de Barcelona, Spain
154. R. Vlahović Kruc, Faculty of Science, University of Zagreb, Croatia
155. A. Wassermann, University of Bayreuth, Germany
156. C. Weiß, Paderborn University, Germany

157. P. Wissing, Tilburg University, The Netherlands
158. S. Zeijlemaker, Eindhoven University of Technology, The Netherlands
159. T. Zhao, University of Birmingham, United Kingdom
160. Y. Zhou, National University of Defense Technology, China
161. L. Zou, National University of Ireland, Galway, Ireland
162. T. Zrinski, University of Rijeka, Croatia
163. M. Zubović, University of Rijeka, Croatia
164. F. Zullo, Università degli Studi della Campania "Luigi Vanvitelli", Italy



Thank you for participating!

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