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Contents

Invited talk

Optimizing carbon nanotubes and graphene production: unraveling the optimal parameters through machine learning

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Abstract

We present the design and development of new technologies for producing carbon nanotubes (CNTs) and graphene by electrolysis in molten salts. The aim is to achieve non-expensive, high-quality materials, making them economically viable for various applications. For the production of multi-walled carbon nanotubes (MWCNTs), we investigate both non-stationary and stationary current regimes, while for graphene production, constant and reversing cell voltage as well as constant and reversing overpotential methods are considered. The electrolysis process offers ecological and economical advantages with precise control over parameters such as applied voltage, current density, temperature, electrolyte type, and graphite material. To determine the relationship between these parameters and material quality, we employ

explainable tree-based Machine Learning (ML) models, trained using labeled data from domain experts. The extracted rules from the ML model guide optimal production, resulting in high-yield materials that are up to ten times more cost-effective than existing technologies. This research contributes to the advancement of cost-efficient and high- quality carbon-based materials for a wide range of applications.

The Borel-Ritt problem in ultraholomorphic classes

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Abstract

A classical result of E. Borel from 1895 states that every formal power series is equal to the Taylor series at 0 of some smooth function on the real line. In 1916, Ritt generalized this result in the following way: Let S be a sector with vertex 0 of the complex plane. Every formal power series is equal to the asymptotic expansion at 0 of some holomorphic function on S. This result is known as the Borel-Ritt theorem.

Ultraholomorphic classes are spaces of holomorphic functions defined on sectors of the complex plane whose derivatives are subject to certain bounds with respect to a given weight sequence. A natural problem is to find analogues of the Borel-Ritt theorem in ultraholomorphic classes. In this talk, we will give an overview of known results and open questions related to this problem.

Quasi-analytic representation theory of $(\mathbb{R}^d, +)$ over quasi-complete locally convex spaces

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Abstract

In [1], Dixmier and Malliavin addressed the following problem. Given a Banach space E, let (π, E) be a representation of a real locally compact Lie group G, i.e. $\pi : G \to GL(E)$ is a homomorphism such that the mapping $G \times E \to E$, $(p, e) \mapsto \pi(g)e$, is continuous. Such representation induces a continuous action Π of the algebra $\mathcal{D}(G)$ on E given by

$$\Pi(f)e = \int_G f(g)\pi(g)edg,\ \ f \in \mathcal{D}(G),\, e \in E,$$

and it restricts to a continuous action to the Banach space of smooth vectors E^∞ consisting of all elements $e \in E$ for which the orbit maps $g \mapsto \pi(g)e$, $G \to E$, are smooth (thus the smooth vectors associated to such a representation are a $\mathcal{D}(G)$-module). Dixmier and Malliavin proved that $E^\infty = \operatorname{span}(\Pi(\mathcal{D}(G))E^\infty) = \operatorname{span}(\Pi(\mathcal{D}(G))E)$; that is, the category of modules E^∞ over the algebra $\mathcal{D}(G)$ satisfies the weak factorisation property. Only recently the analytic variant of this problem was addressed. Namely, by denoting E^ω the space of elements of E whose orbit maps are analytic, the problem of interest here reads: does $E^\omega = \operatorname{span}(\Pi(\mathcal{A}(G))E^\omega)(= \operatorname{span}(\Pi(\mathcal{A}(G))E))$ hold,

where $\mathcal{A}(G)$ is the space of analytic vectors of the (left) regular representation of an appropriate algebra and with it E^ω becomes an $\mathcal{A}(G)$-module? The problem was affirmatively answered by Lienau [3] when $G = (\mathbb{R}, +)$, E is a Banach space and π is a bounded representation. This result was improved by Gimperlein, Krötz, and Lienau [2] by allowing E to be a Fréchet space without the restriction on the boundedness of the representation for general locally compact real Lie group. They obtained the weak factorisation property and $\operatorname{span}(\mathcal{A}(G) * \mathcal{A}(G)) = \mathcal{A}(G)$; in their result $\mathcal{A}(G)$ is the space of analytic vectors of the regular representation of an appropriate convolution algebra.

In this talk we generalise the above result in the following two ways when $G = (\mathbb{R}^d, +)$:

(I) We allow E to be a general quasi-complete locally convex space.

(II) We will solve the problem in the general quasi-analytic case. Namely, we will define the space of ultradifferentiable vectors of Beurling and Roumieu type. Next, we will identify the appropriate convolution algebra over which the space of ultradifferentiable vectors will become a module. Finally, we will show that this category satisfies the factorisation property (without "span").

The talk is based on collaborative works with Andreas Debrouwere and Jasson Vindas.

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Normal 5-edge-colorings and some superpositioned snarks

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Abstract

An edge e is normal in a proper edge-coloring of a cubic graph G if the number of distinct colors on four edges incident to e is 2 or 4. A normal edge-coloring of G is a proper edge-coloring in which every edge of G is normal. The Petersen Coloring Conjecture is equivalent to stating that every bridgeless cubic graph has a normal 5-edge-coloring. Since every 3-edge-coloring of a cubic graph is trivially normal, it is sufficient to consider only snarks to establish the conjecture. We consider a class of superpositioned snarks by choosing a cycle C in a snark G and superpositioning vertices of C by one of two simple supervertices and edges of C by superedges $H_{x,y}$, where H is a snark and x, y a pair of nonadjacent vertices of H. For such snarks, two sufficient conditions are given for the existance of a normal 5-edge coloring. An application of the condition is given for H being a hypohamiltonian snark and/or a Flower snark. The normal colorings of superpositions are constructed from a normal coloring of a snark G by preserving colors outside a cycle C, a situation when this is not possible is also presented. These results immediately yield that for the considered class of snarks the Berge-Fulkerson Conjecture holds, implying thus the results of the paper *[S. Liu, R.-X. Hao, C.-Q. Zhang, Berge–Fulkerson coloring for some families of superposition snarks, Eur. J. Comb. 96 (2021) 103344]*.

Contributed talks

Splitting subspaces of linear operators over finite fields

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Abstract

Let V be a vector space of dimension N over the finite field $\mathbb{F}_q$ and T be a linear operator on V. Given an integer m that divides N, an m-dimensional subspace W of V is T-splitting if $V = W \oplus TW \oplus \cdots \oplus T^{d-1}W$ where $d = N/m$. Let $\sigma(m, d; T)$ denote the number of m-dimensional T-splitting subspaces. Determining $\sigma(m, d; T)$ for an arbitrary operator T is an open problem. We prove that $\sigma(m, d; T)$ depends only on the similarity class type of T and give an explicit formula in the special case where T is cyclic and nilpotent. Denote by $\sigma_q(m, d; \tau)$ the number of m-dimensional splitting subspaces for a linear operator of similarity class type τ over an $\mathbb{F}_q$-vector space of dimension md. For fixed values of m, d and τ, we show that $\sigma_q(m, d; \tau)$ is a polynomial in q.

Structured Output Prediction for Time-to-Event Estimation: A Semi-Supervised Approach in Survival Analysis

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Abstract

A time-to-event estimate is usually obtained through survival analysis. However, standard methods in survival analysis struggle when dealing with categorical and continuous data at once. On the other hand, machine learning methods are only partially suitable for time-to-event analysis, primarily due to censored data. State-of-the-art methods in survival analysis overcome these issues by utilizing a semi-supervised learning model. We present a framework for survival analysis in the context of structured output prediction in a semi-supervised manner. Compared to conventional methods, our method demonstrates superior predictive performance, computational complexity and scalability to high-dimensional inputs. We apply our method on a dataset from Public Employment Services, utilizing it to estimate the time-to-employment for jobseekers. The results demonstrate its effectiveness in prioritizing jobseekers who require immediate assistance, while also highlighting critical factors influencing employment durations. By employing the

SHAP method for interpretability, we gain insights into the model's decisions. Our framework offers a robust and scalable solution for time-to-event estimation, contributing valuable guidance for optimizing support strategies.

Diameter of nanotori

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Abstract

A cubic graph which has only hexagonal faces, and can be embedded into a torus is known as generalized honeycomb torus or honeycomb toroidal graph, abbreviated as nanotorus. This graph is determined by three parameters a, b, and c, and denoted by $G_{a,b,c}$. Recently, B. Alpspach dedicated a survey paper to nanotori, wherein a number of open problems are suggested. In this article we deal with one of the problems given in the survey, i.e. we determine the diameter of nanotorus $G_{a,b,c}$ as a function of the parameters a, b, and c. We obtain that the diameter of $G_{a,b,c}$ for $b \leq a$ is just a. For the case $a < b$, we distinguish two subcases: $a \leq c < b$ and $c < a < b$. In both subcases we determine the diameter for b big enough.

(Join work with Martin Knor and Riste Škrekovski)

Abelian and Tauberian results for the fractional Fourier and short time Fourier transforms

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Abstract

We introduce the fractional short time Fourier transform in $\mathcal{S}'(\mathbb{R})$ and provide generalized asymptotics for the fractional Fourier and the short time Fourier transforms within $\mathcal{S}'(\mathbb{R})$. Abelian and Tauberian type results are given.

H-integral and Gaussian integral normal mixed Cayley graphs

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Abstract

If all the eigenvalues of the Hermitian-adjacency matrix of a mixed graph are integers, then the mixed graph is called H-integral. If all the eigenvalues of the (0,1)-adjacency matrix of a mixed graph are Gaussian integers, then the mixed graph is called Gaussian integral. In this talk, we characterize H-integral normal mixed Cayley graph over a finite group. We further prove that a normal mixed Cayley graph is H-integral if and only if the mixed graph is Gaussian integral.

Omega Invariant and Combinatorial Properties

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Abstract

Omega invariant is a graph parameter which is closely related to the Euler characteristic and the cyclomatic number of a graph. It has been applied to many combinatorial problems related to several graph parameters, some counting algorithms, topological indices etc. In this talk, we shall summarize some of the latest combinatorial results and answer some open problems related to realizability of a given degree sequence.

Uniformly concentrated partitions of unity and its application

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Abstract

We define Wiener amalgam spaces of (quasi)analytic ultradistributions whose local components belong to a general class of translation and modulation invariant Banach spaces of ultradistributions and global components are either weighted L^p or a weighted $\mathcal{C}_0$ spaces. We provide a discrete characterisation via so called uniformly concentrated partitions of unity. We identify the strong duals for most of these Wiener amalgam spaces. (Joint

work with Bojan Prangoski, Faculty of Mechanical Engineering, Ss. Cyril and Methodius University in Skopje, North Macedonia.)

On metric dimension of circulant graphs with t consecutive generators

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Abstract

Let G be a graph, and let W be an ordered set of k vertices of G, say $W = (v_1, v_2, \ldots, v_k)$. For $u \in V(G)$ we define

$$r(u|W) = (d(u, v_1), d(u, v_2), \ldots, d(u, v_k)),$$

where $d(u, v)$ is the distance from u to v in G. If for every $u_1, u_2 \in V(G)$ the vectors $r(u_1|W)$ and $r(u_2|W)$ are different whenever $u_1 \neq u_2$, then W is the **metric basis** of G. **Metric dimension** of G, $dim(G)$, is the cardinality of a minimum metric basis in G.

The circulant graph $C_n(1, 2, \ldots, t)$ is the Cayley graph

$$Cay(\mathbb{Z}_n, \{\pm 1, \pm 2, \ldots, \pm t\}).$$

We prove that the metric dimension of $C_n(1, 2, \ldots, t)$ is at least $\lceil \frac{2t}{3} \rceil + 1$ and we completely characterize the cases when equality is attained. As a consequence, we completely determine $dim(C_n(1, 2, \ldots, 5)$, that is when the graph has exactly 5 consecutive generators.

(Joint work with Riste Škrekovski and Tomas Vetrik.)

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Abstract

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Abstract

Proper edge-colorings with a rich neighbor condition

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Abstract

Under a given edge-coloring of a (multi)graph G, an edge is said to be *rich* if there is no color repetition among its neighboring edges; e.g., any isolated or pendant edge is rich. If every edge in the graph is rich, then the coloring is termed *strong*. This coloring notion has been introduced back in the 1980s and has been extensively researched ever since. One readily observes the following: a proper edge-coloring of G is strong if and only if for any edge $e \in E(G)$ each of its neighboring edges is rich.

In this talk, we discuss a weaker variant of strong edge-colorings, inspired by the above observation. A *rich-neighbor coloring* of a graph G is a proper edge-coloring such that every non-isolated edge has at least one rich neighbor. It is our belief that every connected subcubic graph $\neq K_4$ admits a rich-neighbor 5-coloring. As a first support of this we present our recent result stating that every subcubic graph admits a rich-neighbor coloring with at most 7 colors. The talk concludes with few open problems for subcubic graphs concerning the analogous notions of normal-neighbor colorings and poor-neighbor colorings.

(Joint work with Riste Škrekovski)

The Odd Coloring

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Abstract

A proper vertex coloring φ of graph G is said to be odd if for each non-isolated vertex $x \in V(G)$ there exists a color c such that $\varphi^{-1}(c) \cap N(x)$ is odd-sized. The minimum number of colors in any odd coloring of G, denoted $\chi_o(G)$, is the odd chromatic number. Odd colorings were recently introduced in [M. Petruševski, R. Škrekovski: *Colorings with neighborhood parity condition*]. In the talk we discuss various basic properties of this new graph parameter, establish several upper bounds, several charatcterizatons, and pose some questions and problems. We will also consider another new and related coloring, so called the proper conflict-free coloring.

(Join work with Mirko Petruševski and Yair Caro)

The Indian Charter on Planet Earth, the European Decentralization Activities, and a Walk-Through the Next Generation Internet Agenda

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Abstract

During thousands of years of cultural history, humanity has generated a huge body of knowledge. In its core this knowledge relates to our understanding of the natural world, the society and its rules for co-existence, our care for the environment. However, as evidence on every step shows, humanity in the past hundred years using various technologies, is losing its link to this deeply generated knowledge. Today's software technologies, such as the Internet of Things, Cloud-to-Edge computing, Artificial Intelligence, Blockchain, and Digital Twins could be used to embed this deep knowledge into the core structure of the Internet, so that software technology can better serve our humanity needs. Various Next Generation Internet projects, such as DECENTER, ONTOCHAIN, TRUSTCHAIN, BUILDCHAIN, EXTREME-XP, EBSI-VECTOR and similar intend to produce exactly that, a modern knowledge infrastructure that embeds core principles of humanity in its operation for the benefit of more trustworthy, human-rights compliant and sustainable Internet.

Shedding Vertices and Their Recognition

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Abstract

An *independent set* of vertices in a graph is a set of vertices whose elements are pairwise nonadjacent. An independent set is *maximal* if it is not a subset of another independent set. An independent set is *maximum* if the graph does not contain an independent set of a higher cardinality. The cardinality of a maximum independent set in G is denoted $\alpha(G)$. Finding a maximum independent set in an input graph is known to be an NP-complete problem.

A graph G is *well-covered* if all its maximal independent sets are maximum, i.e. the size of every maximal independent set is $\alpha(G)$. Finding a maximum independent set in a well-covered graph can be done polynomially, using the greedy algorithm. Recognizing well-covered graphs is known to be in co-NP-complete [2, 7]. Let $w : V(G) \longrightarrow \mathbb{R}$. Then G is w-well-covered if all maximal independent sets of G are of the same weight. For every graph G the set of functions $w : V(G) \longrightarrow \mathbb{R}$ such that G is w-well-covered is a vector space, denoted $WCW(G)$ [1].

Let $k \geq 1$. A graph G belongs to class $\mathbf{W_k}$ if every k pairwise disjoint independent sets in G are included in k pairwise disjoint maximum independent sets [8]. It holds that $\mathbf{W_1} \supseteq \mathbf{W_2} \supseteq \mathbf{W_3} \supseteq \ldots$, where $\mathbf{W_1}$ is the family

of all well-covered graphs. The complexity status of recognizing $\mathbf{W_2}$ graphs is open for both general graphs and well-covered graphs.

A vertex $v \in V(G)$ is *shedding* if for every independent set $S \subseteq V(G) \setminus N[v]$ there exists $u \in N(v)$ such that $S \cup \{u\}$ is independent. Equivalently, v is shedding if there does not exist an independent set in $V(G) \setminus N[v]$ which dominates $N(v)$ [9]. Theorem 1 shows the connection between shedding vertices and $\mathbf{W_2}$ graphs.

Theorem 1. *[4, 5] For every well-covered graph G having no isolated vertices, the following assertions are equivalent:*

1. *G is in the class $\mathbf{W_2}$.*
2. *$G \setminus N[v]$ is in the class $\mathbf{W_2}$, for every $v \in V(G)$.*
3. *All vertices of G are shedding.*

The complexity status of recognizing shedding vertices in well-covered graphs is not known. However, we prove the following.

Theorem 2. *The following problem is co-NP-complete.*
Input: A graph G without cycles of length 3, and a vertex $v \in V(G)$.
Question: Is v shedding?

The proof of Theorem 2 includes a polynomial reduction from the **SAT** problem, which is well-known to be NP-complete [3].

Let G be a graph and $xy \in E(G)$. Then xy is *relating* if there exists an independent set $S \subseteq V(G) \setminus N[\{x, y\}]$ such that each of $S \cup \{x\}$ and $S \cup \{y\}$ is a maximal independent set of G [6]. Recognizing relating edges is known to be NP-complete [1]. Relating edges play an important role in finding $WCW(G)$.

Non-shedding verices and relating edges are closely related notions. A witness for their existence is an independent set of vertices, which dominates all vertices of the graph except the non-shedding vertex or the endpoints of the relating edge. Moreover, there exists a polynomial reduction from recognizing relating edges to recognizing non-shedding vertices. Additionally, Theorem 3 shows a connection between non-shedding vertices and relating edges.

Theorem 3. *Let G be a graph without cycles of lengths 4, 5 and 6, and $xy \in E(G)$. Suppose $N(x) \cap N(y) = \varnothing$, $d(x) \geq 2$ and $d(y) \geq 2$. The following assertions are equivalent:*

1. *None of x and y is a shedding vertex.*

2. *xy is a relating edge.*

(joint work with Vadim E. Levit,Department of Mathematics, Ariel University, Ariel, Israel
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Decomposition of complete graph into trees and cyclescycles

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Abstract

Almost Periodicity in Abstract Impulsive Volterra Integro-Differential Inclusions

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Abstract

During this talk, we will showcase a variety of practical applications that utilize (a, k)-regularized C-resolvent families for solving abstract impulsive Volterra integro-differential inclusions. We will introduce and thoroughly analyze new categories of piecewise continuous functions of an almost periodic type, with values in complex Banach spaces. We will also provide results regarding the existence and uniqueness of almost periodic type solutions for specific classes of abstract impulsive Volterra integro-differential inclusions. In addition, we will demonstrate numerous applications of the results on the existence and uniqueness of almost periodic solutions for various classes of abstract impulsive Volterra integro-differential inclusions.

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Notes