Frontiers in Combinatorics - Topology, Algebra and Data-Driven Insights

Conference Schedule & Details

July 06-10, 2026

Plenary Talks @ 10:00 AM

Day 1: Enumerative combinatorics in the Alternating group A_n and more

Prof. S. Sivaramakrishnan, *IIT Bombay*

Enumeration of several combinatorial statistics in A_n surprisingly gives clean results. In this talk, we cover two such statistics, excedance and descent-length. Apart from getting clear answers, we are also able to get the mean and sometimes Central Limit Theorems for the random variable that takes these statistics as values when permutations are sampled from A_n.

Extensions to type B and type D Coxeter groups are given whenever applicable. Proofs seem to make use of various bijective techniques and are many times of independent interest.

Day 2: From Lovász to Persistent Homology : The evolution of Topological methods in Discrete Mathematics and Data Analysis

Prof. Nandini Nilakantan, *IIT Kanpur*

The proof of Kneser's conjecture by László Lovász initiated a profound interaction between topology, combinatorics, and algebra. By associating simplicial complexes to graphs and exploiting equivariant topological obstructions derived from the Borsuk–Ulam Theorem, Lovász demonstrated that global topological invariants can yield sharp combinatorial consequences. This insight became a cornerstone of topological combinatorics and inspired a broad program of translating discrete structures into topological objects whose invariants capture essential combinatorial information.

In this talk, we trace the development of this philosophy from Lovász's work to contemporary Topological Data Analysis (TDA). We first highlight how topological obstructions arise naturally from discrete data, then turn to the simplicial constructions that underlie TDA and reveal deep connections with algebra. We will survey many directions in modern TDA, underlying and emphasising the passage from discrete structures to topological spaces and the extraction of robust algebraic invariants that encode hidden global organization.

Day 3: The shape of data through graph

Prof. Priyavrat Deshpande, *Chennai Mathematical Institute*

Graphs provide an effective mechanism for representing complex datasets, ranging from social and biological networks to high-dimensional point clouds arising in modern data analysis. Over the past two decades, spectral graph theory has emerged as one of the central mathematical tools for extracting geometric and structural information from such data.

In this talk, I will briefly explain how eigenvalues and eigenvectors of graph Laplacians can be used to address two fundamental tasks: dimensionality reduction and clustering. Beginning with motivating examples and applications, I will introduce the ideas underlying spectral clustering and Laplacian eigenmaps, emphasizing the role of graph spectra in uncovering hidden geometric structure.

Finally, I will discuss recent ongoing work involving the resistance Laplacian and its potential advantages for clustering and data analysis. Along the way, I will try to highlight several open problems and research directions that illustrate how ideas from combinatorics and spectral graph theory continue to influence modern data science.

Day 4: Commutative Algebra of Random Graphs

Prof. Arindam Banerjee, *IIT Kharagpur*

Random graphs and random simplicial complexes have generated active research blending combinatorics with probability. In this topic we shall bring a commutative algebra dimension to this picture. We shall discuss some random versions of active research problems in combinatorial commutative algebra and some laws of large numbers about random monomial ideals. At the end we aim to discuss some potential role of AI and ML in research of commutative algebra.

Day 5: Alternating Sign Matrices, Plane Partitions, And All That

Prof. Manjil Saikia, *Ahmedabad University*

Alternating sign matrices (ASMs) are square matrices with entries in $\{0,1,-1\}$, whose rows and columns sum to 1, and whose nonzero entries alternate in sign. Their enumeration, famously conjectured by Mills, Robbins, and Rumsey and later proved by Zeilberger and Kuperberg, is one of the central stories of modern enumerative combinatorics. In this talk, I will give an introduction to alternating sign matrices, their symmetry classes, refined enumeration problems obtained by fixing the position of boundary 1's, plane partitions, their connections to ASMs, and several other related objects.

Several open problems will be presented (some open for many decades, but also some which are at a beginning graduate/postdoc level). As my objects of choice, I will mostly look at ASMs having vertical symmetry (VSASMs) and/or half-turn symmetry. Time permitting, I will explain how the six-vertex model and its partition functions provide a powerful framework for proving identities related to ASM enumeration, and some unusual refined enumerations related to VSASMs.

The talk will mostly be self-contained, but fast-paced, as we try to unravel the story of ASMs, and several connections to other objects/areas which we do not yet understand. For participants who wish to look at these objects before the talk, here are three articles written for a general audience (in increasing order of difficulty):

https://ganitbikash.aamonline.org.in/gb/volume-67/11-The-Remarkable-Sequence-Manjil-P-Saikia.pdf,

https://www.imaginary.org/sites/default/files/snapshots/snapshot-2026-003.pdf, and

https://www.mat.univie.ac.at/~ifischer/papers/asmpnas.pdf.

Contributed Talks @ 2 PM

Day 1, Talk 1: Homotopy type of matching complexes of grid graphs

Ms. Anchal Sharma, *IIT Mandi*

Let G be a graph with vertex set $V(G)$ and edge set $E(G)$. A graph complex is a simplicial complex associated to a graph, where the simplices are determined by using certain combinatorial properties of the graph. Numerous graph complexes have been introduced and extensively studied, including the neighborhood complex, independence complex, clique complex, and matching complex.

The matching complex $M(G)$ is a simplicial complex whose vertex set is $E(G)$, and whose simplicies are the matchings of G. The independence complex $\mathrm{Ind}(G)$ is a simplicial complex whose vertex set is $V(G)$, and whose simplicies are the independent sets of G.

The line graph $L(G)$ is a graph with vertex set $E(G)$, with two distinct vertices $(u_1, u_2), (v_1, v_2)$ in $L(G)$ adjacent if and only if $(u_1, u_2) \cap (v_1, v_2) \neq \emptyset$. It is well known that the $M(G) = \mathrm{Ind}(L(G))$, a classical result reducing the study of matching complexes to that of independence complexes of line graphs.

The *Cartesian product* of graphs G and H, denoted by $G \square H$, is the graph where $V(G \square H) = V(G) \times V(H)$ and $E(G \square H) = \{\{(g, h), (g', h')\}: g = g' \text{ and } \{h, h'\} \in E(H), \text{ or } h = h' \text{ and } \{g, g'\} \in E(G)\}$. The $m \times n$ grid graph $G_{m \times n}$ is defined as the Cartesian product $P_m \square P_n$ of path graphs on m and n vertices.

The matching complex of grid graphs $M(G_{m \times n})$ has attracted considerable attention in recent years. Many authors have studied the topological and combinatorial properties of $M(G_{m \times n})$. In particular, this talk focuses on the homotopy type of $M(G_{m \times n})$.

Day 1, Talk 2: On the Majority Game Chromatic Number of Trees

Mr. Yash Chawda, *IIT Jodhpur*

A majority coloring of a graph is a vertex coloring in which no vertex has more than half of its neighbors colored with its own color. The least number of colors required for such a coloring is the majority chromatic number. In the corresponding coloring game, two players alternately color vertices while maintaining the majority condition; the least number of colors for which the first player has a winning strategy is the majority game chromatic number $\mu_g(G)$ for the graph G. It is known that $\mu_g(G)$ is unbounded in general, while $\mu_g(T) \leq 3$ for complete binary trees. In this note we study $\mu_g(G)$ for trees, with emphasis on ternary trees. We introduce a configuration-based strategy for the first player, identify minimal local obstructions that could force a fourth color, and show that these configurations do not arise in ternary trees. As a consequence, $\mu_g(T) \leq 3$ for every ternary tree. We further extend the result to trees in which all vertices, except the leaves, have even degree.

Day 2, Talk 1: The Difference Graph with genus and cross cap 2

Ekta, *BITS Pilani, Pilani Campus*

The power graph $P(G)$ of a finite group G is a simple undirected graph with vertex set G and two vertices are adjacent if one is a power of the other. The intersection power graph $\mathrm{G1}(G)$ of a finite group G is a simple undirected graph with vertex set G and two vertices x, y are adjacent if $\langle x \rangle \cap \langle y \rangle \neq \{e\}$. The difference graph $D(G)$ of a finite group G is the difference of the intersection power graph $\mathrm{G1}(G)$ and power graph $P(G)$ with all isolated vertices removed. We characterized all the finite nilpotent groups G such that the difference graph is planar. Further, we determine all the finite nilpotent groups whose difference graph has genus at most 2. Moreover, we prove that there does not exist any group whose difference graph has cross-cap one.

Day 2, Talk 2: Genus and Crosscap of Normal Subgroup Based Power Graphs

Ms. Manisha, *BITS Pilani, Pilani Campus*

Let H be a normal subgroup of a group G. The normal subgroup based power graph $\Gamma H(G)$ of G is the simple undirected graph with vertex set $V\big(\Gamma H(G)\big) = (G \backslash H) \cup \{e\}$ and two distinct vertices a and b are adjacent if either $aH = (b^m)H$ or $bH = (a^n)H$ for some $m, n \in \mathbb{N}$. In this paper, we continue the study of normal subgroup based power graph and characterize all the pairs (G, H), where H is a non-trivial normal subgroup of G, such that the genus of $\Gamma H(G)$ is at most 2. Moreover, we determine all the subgroups H and the quotient groups G/H such that the cross-cap of $\Gamma H(G)$ is at most three.

Day 3, Talk 1: Buchsbaumness of finite complement simplicial affine semigroups

Dr. Om Prakash, *Chennai Mathematical Institute*

In this work, we classify all Buchsbaum simplicial affine semigroups whose complement in their integer cone is finite. We show that such a semigroup is Buchsbaum if and only if its set of gaps is equal to its set of pseudo-Frobenius elements. Furthermore, we provide a complete structure of these affine semigroups.

Day 3, Talk 2: Support-2 Monomial Ideals that are Simis

Ms. Paromita Bordoloi, *IIT Jammu*

A monomial ideal I in $K[x_1, \dots, x_n]$ is called a Simis ideal if $I^{(s)} = I^s$ for all positive integers s, where $I^{(s)}$ denotes the s-th symbolic power of I. Let I be a support-2 monomial ideal such that its irreducible primary decomposition is minimal. We prove that I is a Simis ideal if and only if radical of I is Simis and I has a standard linear weighting. This result thereby proves a recent conjecture for the class of support-2 monomial ideals proposed by Mendez, Pinto, and Villarreal. Furthermore, we give a complete characterization of the Cohen-Macaulay property for support-2 monomial ideals whose radical is the edge ideal of a whiskered graph. Finally, we classify when these ideals are Simis in degree 2.

Day 4, Talk 1: On vertex connectivity of annihilator graphs of commutative rings

Mr. Mohd Shariq, *BITS Pilani, Pilani Campus*

The annihilator graph $\mathrm{AG}(R)$ of the commutative ring R is an undirected simple graph whose vertex set is the set of non-zero zero-divisors of R, and two distinct vertices x and y are adjacent if and only if $\mathrm{ann}(xy) \neq \mathrm{ann}(x) \cup \mathrm{ann}(y)$. In this manuscript, we show for a commutative ring R that the vertex connectivity and the minimum degree of the annihilator graph $\mathrm{AG}(R)$ are equal. Moreover, we obtain the cut set of the annihilator graph $\mathrm{AG}(R)$, where R is a reduced ring. Finally, we determine the vertex connectivity of $\mathrm{AG}(R)$.

Day 4, Talk 2: Spectrum of Conjugacy Super Generating Graphs defined on Certain Groups

Mr. Rahul Kumar, *BITS Pilani, Pilani Campus*

Given a simple graph A on a group G and an equivalence relation B on G, then the B super A graph is defined as a simple graph, whose vertex set is G and two vertices g, h are adjacent if either they are in the same equivalence class or there exist $g' \in [g]$ and $h' \in [h]$ such that g' and h' are adjacent in A. In the literature, the B super A graphs have been investigated by considering A to be either power graph, enhanced power graph, or commuting graph and B to be an equality, order or conjugacy relation. In this paper, we investigate the Laplacian spectrums of B super A graph by considering A to be the generating graph and B to be conjugacy relation for certain non-abelian groups, viz. the generalized quaternion group, dihedral group, and the semidihedral group, respectively. We prove that the graphs considered in this paper are Laplacian integral.

Day 5: Hilbert coefficients and regularity of binomial edge ideals

Mr. Paramhans Kushwaha, *IIT Jammu*

In this talk, we begin with a brief overview of Hilbert function and Hilbert coefficients. The binomial edge ideal J_G in the appropriate polynomial ring S arising from a finite simple graph

G has various interesting properties in terms of the underlying graph G. We prove that if a vertex satisfies a certain degree condition, then some Hilbert coefficients remain unchanged upon its removal. We then prove that there is no inherent relationship between the regularity and the Hilbert coefficients for the class of binomial edge ideals. For this, we construct graphs for every possible pair $(r, s_i), r \geq 1$ and $s_i \in \mathbb{Z}$ for $i \geq 0$, where r is the Castelnuovo-Mumford regularity and s_i is the i-th Hilbert coefficient of S/J_G. This talk is based on joint work with Dr. Kanoy Kumar Das and Prof. Rajiv Kumar.