Symposium on 'Topics in Algebraic Geometry'

Organisers: *Ramesh Sreekantan* (Indian Statistical Institute, Bangalore, India) and *Patrick Brosnan* (University of Maryland, USA)

A^1-Connectedness in Reductive Groups

Chetan Balwe
IISER Mohali, India

We examine the notion of A^1-connectedness, in the sense of the A^1-homotopy theory of Morel-Voevodsky, on schemes, focusing specifically on reductive groups. We do so by comparing this notion with the equivalence relation on points induced by "naive" A^1-homotopies. This allows us to employ geometric methods and, in some cases, relate the sheaf of A^1-connected components with the notion of R-equivalence. We obtain a complete characterization of A^1-connected reductive groups. This talk is based on joint work with Anand Sawant.

Hessenberg Varieties and the Shareshian-Wachs Conjecture

Patrick Brosnan
University of Maryland, USA

I will explain joint work with Tim Chow, which proves a conjecture of Shareshian and Wachs relating Hessenberg varieties to chromatic symmetric polynomials.

Hodge Theory on Matroids

Eric Katz
Ohio State University, USA

The chromatic polynomial of a graph counts its proper colourings. This polynomial's coefficients were conjectured to form a unimodal sequence by Read in 1968. This conjecture was extended by Rota in his 1970 address to assert the log-concavity of the characteristic polynomial of matroids which are the common generalizations of graphs and linear subspaces. We discuss the resolution of this conjecture which is joint work with Karim Adiprasito and June Huh. The solution draws on ideas from the theory of algebraic varieties, specically Hodge theory, showing how a question about graph theory leads to a solution involving Grothendieck's standard conjectures.

Bloch-Quillen Formula for Singular Schemes

Amalendu Krishna
Tata Institute of Fundamental Research, Mumbai, India

The Bloch-Quillen formula in the theory of algebraic cycles provides a formula for the Chow groups of 0-cycles on a smooth quasi-projective scheme in terms of the Zariski cohomology of the Quillen K-theory sheaves. Such a formula for singular schemes is not yet known, except in some very special cases. In this talk, I will present such a formula of certain class of singular schemes.

Modular Forms and Higher Chow Cycles

Ramesh Sreekantan
Indian Statistical Institute, Bangalore, India

A consequence of some conjectures in Arithmetic Algebraic Geometry is a link between higher Chow cycles on the self-product of the universal abelian surface over a Shimura curve and modular forms on the curve. We will explain this precisely and prove the conjecture in the special case when the family is the self-product of the universal elliptic curve over a modular curve. As a result of this we obtain some results on the algebraicity of higher Greens functions predicted by Gross and Zagier.

Motivic Intersection Complex of an Arbitrary Threefold

Vaibhav Vaish
Indian Statistical Institute, Bangalore, India

We formalize a notion of "punctual gluing" of t-structures. This allows us to construct analogue of certain S.Morel's weight truncations in the motivic setting. As an application we can construct the analogue of intersection complex for an arbitrary threefold in Voevodsky's triangulated category of mixed motives.

Symposium on Algebraic Groups

Organisers: *K.N. Raghavan* (IMSc, Chennai, India)
and *V. Lakshmibai* (Northeastern University, Boston, USA)

Elliptic Quantum Groups

Sachin Gautam
Perimeter Institute for Theoretical Physics, Canada

In 1995 G. Felder introduced an elliptic R-matrix, which quantizes the classical dynamical r-matrix arising from the study of conformal blocks on elliptic curves. The elliptic R-matrix satisfies a dynamical analog of the Yang-Baxter equation and can be used to define the elliptic quantum group of sl_n in the same vein as the usual R-matrices gives rise to quantum groups via the RTT formalism of Faddeev, Reshetikhin and Takhtajan.

In this talk I will explain Felder's definition and present its generalization to the case of arbitrary Kac-Moody Lie algebras analogous to the Drinfeld's new presentation of Yangians and quantum loop algebras. I will also present a method of constructing representations of the elliptic quantum group using q-difference equations. Our construction gives rise to a classification of irreducible representations of the elliptic quantum group, which is reminiscent of the Drinfeld's classification of irreducible representations of Yangians. This talk is based on a joint work with V. Toledano Laredo.

Representation Ring of Levi Subgroups versus Cohomology Ring of Flag Varieties

Shrawan Kumar
University of North Carolina, Chapel Hill, USA

Recall the classical result that the cup product structure constants for the singular cohomology with integral coefficients of the Grassmannian of r-planes coincide with the Littlewood-Richardson tensor product structure constants for $\mathrm{GL}(r)$. Specifically, the result asserts that there is an explicit ring homomorphism $\phi : \mathrm{Rep}_{\mathrm{poly}}(\mathrm{GL}(r))$ to $H^*(\mathrm{Gr}(r,n))$, where $\mathrm{Gr}(r,n)$ denotes the Grassmannian of r-planes in C^n and $\mathrm{Rep}_{\mathrm{poly}}(\mathrm{L}(r))$ denotes the polynomial representation ring of $\mathrm{GL}(r)$.

This talk seeks to achieve one possible generalization of this classical result for $\mathrm{GL}(r)$ and the Grassmannian $\mathrm{Gr}(r,n)$ to the Levi subgroups of any reductive group G and the corresponding flag varieties.

On Complete Reducibility in Characteristic p

A. J. Parameswaran
Tata Institute of Fundamental Research, Mumbai, India

Serre showed that if semi-simple representations V_i of a group Γ are such that $\sum(dimV_i - 1) < p$, then their tensor product is semisimple. Later he proved that semisimple representations restrict to semisimple representations of a subgroup Γ if it is a G_{cr} subgroup.

Recently, Deligne generalized the first result to doubly saturated subgroup schemes of a reductive group. In this talk, we consider the case when Γ is a doubly saturated G_{cr} subgroup scheme of a reductive group G and generalize Serre's results to low height representations. Further we show an analogue of Luna's étale slice theorem for low height representations of reductive groups.

This is a joint work with V. Balaji and P. Deligne.

Odd Dimensional Representations in Bratelli Diagrams of Weyl Groups and Bijective McKay Correspodences

Amritanshu Prasad
Institute of Mathematical Sciences, Chennai, India

The induced subgraphs formed by odd-dimensional representations in the Bratelli diagrams of Weyl groups of type A_n, B_n and D_n turn out to have surprisingly nice structure. This structure suggests explicit bijections between the odd dimensional representations of these groups and one-dimensional representations of their 2-Sylow subgroups (bijective McKay correspondences). This talk is based on joint work with Arvind Ayyer, Karimilla Bi, and Steven Spallone.

A Polynomial Time Algorithm to Determine Membership in the Null Cone of Matrix Semi-invariants

Venkata Subrahmanyam
Chennai Mathematical Institute, Chennai, India

In 1967, J. Edmonds introduced the problem of computing the rank over the rational function field of an $n \times n$ matrix T with integral homogeneous linear polynomials. We consider the *non-commutative version of Edmonds'problem*: compute the rank of T over the free skew field. This problem has been proposed from several different perspectives in the study of, for example, the free skew field itself (Cohn 1973), matrix spaces of low rank (Fortin-Reutenauer,2004), Edmonds' original problem (Gurvits, 2004), and more recently, non-commutative arithmetic circuits with divisions (Hrubeš and Wigderson, 2014).

It is known that this problem relates to the following invariant ring of matrix semi-invariants denoted $R(n, m)$. For a field F it is the ring of invariant polynomials for the action of $SL(n; F) \times SL(n; F)$ on tuples of matrices - $(A, C) \in SL(n; F) \times SL(n; F)$ sends $(B_1, ..., B_m) \in M(n; F)^{\oplus m}$ to $(AB_1C^T, ..., AB_mC^T)$. Then those T with non-commutative rank $< n$ correspond to points in the nullcone of $R(n, m)$.

Recently Garg et al. (FOCS 2016) showed that the non-commutative rank problem is in P over Q, building on an algorithm of Gurvits (JCSS 2004).

Our main result is a deterministic algorithm for the non-commutative rank problem using polynomially many arithmetic operations over *any field*. Over Q the bit complexity of the algorithm is also polynomial. It is *constructive* in that it produces witnesses certifying the non-commutative rank. We give another proof that the nullcone of $R(n, m)$ is defined by invariants of polynomial degrees, a result recently proved by Derksen and Makam (arXiv:1512.03393). This is joint work with Gĺabor Ivanyos and Yoming Qiao.

Equivariant K-Theory of Flag Varieties Revisited and Related Results

V. Uma
Indian Institute of Technology, Madras, India

In this talk we shall obtain many results on the multiplicative structure constants of the T-equivariant Grothendieck ring $K_T(G/B)$ of the flag variety G/B. We shall do this by lifting the classes of structure sheaves of Schubert varieties in $K_T(G/B)$ to $R(T) \otimes R(T)$, where $R(T)$ denotes the representation ring of the torus T. We shall further apply our results to describe the multiplicative structure constants of $K(X)_Q$ where X denotes the wonderful compactification of the adjoint group of G, in terms of the structure constants of Schubert varieties in the Grothendieck ring of G/B.

Symposium on 'Analysis'

Organiser: *Ajit Iqbal Singh* (INSA Emeritus Scientist, New Delhi, India)

The $\overline{\partial}$-Problem in Pseudoconcave Annuli

Debraj Chakrabarti
Central Michigan University, USA

One of the fundamental problems of several complex variables is to construct holomorphic functions and other analytic objects with prescribed properties. Often, this can be reduced to solving the system of inhomogeneous Cauchy-Riemann equations with estimates in a particular norm – known as the $\overline{\partial}$-problem . In 1965, Hormander showed that in bounded pseudoconvex domains, the $\overline{\partial}$-problem can be solved with L^2 estimates.

We consider the question of solving the $\overline{\partial}$-problem in the annulus bounded by two pseudoconvex domains, where the "hole" is allowed to be nonsmooth. We obtain estimates for this problem in L^2-spaces using a gluing technique, and prove vanishing results for the $L^2 - \overline{\partial}$-cohomology.

This is joint work with Mei-Chi Shaw (Notre Dame) and Christine Laurent-Thiébaut (Grenoble).

The Bidual of C(K)

Frederick K. Dashiell, Jr.
University of California, Los Angeles, USA

It has long been known that the second Banach dual of $C(K)$, for a compact space K, is linearly and algebraically isometric to a Banach algebra of the same type, which we call $C(\widetilde{K})$. However, the compact space $\widetilde{K}$, and its relationship to K, has been rather less well

understood. The name *hyper-Stonean* was bestowed by Dixmier for the class of compact spaces X such that $C(X)$ is a Banach dual. The spaces $X = \widetilde{K}$ form a proper subclass, $C(\widetilde{K})$ being a *second dual*. Every hyper-Stonean space is extremally disconnected, so it represents a certain unique complete Boolean algebra. One question addressed here is: how does the topological data of a compact K give rise to the algebraic object, namely the complete Boolean algebra represented by $\widetilde{K}$? This talk presents several approaches to $\widetilde{K}$, and investigates the question of characterizing those X for which $C(X)$ is the *second dual* of a Banach space.

This discussion is based on the forthcoming book *Banach Spaces of Continuous Functions as Dual Spaces*, CMS Books in Mathematics, Springer–Verlag, co-authored by myself, H. Garth Dales, Anthony To-Ming Lau, and Dona Strauss.

Quantum Isometry Groups

Debashish Goswami
Indian Statistical Institute, Kolkata, India

I give a brief sketch of the theory of quantum isometry groups formulated by me and studied by several other mathematicians over the last few years. Some examples and open problems will be discussed too. In particular, I'll mention some results which were outcome of my collaboration with Bhowmick, Mandal, Banica, Skalski, Joardar, Etingof and Walton.

A Unified Framework for Harmonic Analysis of Functions on Directed Graphs and Changing Data

Hrushikesh Mhaskar
Department of Mathematics, California Institute of Technology, Pasadena, CA 91125, U.S.A.; Institute of Mathematical Sciences, Claremont Graduate University, Claremont, CA 91711, U.S.A.

Diffusion geometry is a recent powerful tool for analyzing high dimensional, unstructured data by embedding it on a low dimensional manifold. We present a general framework for studying harmonic analysis of functions in the settings of various emerging problems in the theory of diffusion geometry. The starting point of the now classical diffusion geometry approach is the construction of a kernel whose discretization leads to an undirected graph structure on an unstructured data set. We study the question of constructing such kernels for directed graph structures, and argue that our construction is essentially the only way to do so using discretizations of kernels. We then use our previous theory to develop harmonic analysis based on the singular value decomposition of the resulting non–self–adjoint operators associated with the directed graph. Next, we consider the question of how functions defined on one space evolves to another space in the paradigm of changing data sets recently introduced by Coifman and Hirn. While the approach of Coifman and Hirn require that the

points on one space should be in a known one–to–one correspondence with the points on the other, our approach allows the identification of only a subset of landmark points. We introduce a new definition of distance between points on two spaces, construct localized kernels based on the two spaces and the landmark points, and study the evolution of smoothness of a function on one space to its lifting to the other space via the landmarks. We develop novel mathematical tools that enable us to study these seemingly different problems in a unified manner.

Commutativity in Operator Algebras

Lajos Molnar
University of Szeged and Budapest University of Technology and Economics, Hungary

Commutativity in structures of matrices and linear operators is an important relation having many applications within mathematics and also in physics. In this talk we present some of our recent results concerning characterizations of commutativity of C^*-algebras, descriptions of central elements in general C^*-algebras and characterizations of commuting pairs of Hilbert space operators.

Geometrical Properties of Sets In Banach Spaces: Simple Problems, Trivial or Non Trivial Answers?

Pier Luigi Papini
University of Bologna, Italy

In this talk we shall indicate some problems whose formulation is easy but whose solution, for some of them, is not at all trivial.

Consider in a Banach space (of any dimension) the class of closed, bounded and covex sets. Interesting subclasses of sets arise if we consider properties like these:

a) a set has constant width;

b) the addition of any point to a set A increases its diameter (A is *complete*);

c) the subtraction of any point to a set A decreases its minimal width (A is *reduced*).

The relations among them, and some open problems will be discussed.

New classes of sets can be defined by using properties that "nearly" characterize closed balls:

d) the addition of any point to a set A increases its radius;

e) the removal of any point from a set A decreases its inner radius.

Results concerning the last properties rely on existence of centers or incenters, so rather pathological spaces and sets are involved. Moreover, we study the relations among the two types of conditions.

We shall also indicate some properties of the Jung constant, together with some open problems concerning it.

Weakly Almost Periodic Functions and Compactifications

Wolfgang A. F. Ruppert
Institute of Mathematics, DIB, The University of Natural Resources and Life Sciences, Gregor-Mendel-Straße 33 1180 Wien, Austria

The aim of this talk is to give a short survey over weakly almost periodic functions and the associated compactifications, presenting the main known results as well as some of the more recent developments. Special emphasis will be given to open problems.

Ramanujan Graphs from Finite Free Convolutions

Nikhil Srivastava
University of California, Berkeley, USA

We show that a random d-regular bipartite graph has an optimally large spectral gap with nonzero probability. Notably, we use tools inspired by asymptotic (i.e., large n limit) random matrix theory to prove statements about finite dimensional matrices. The mediating role is to be played by the expected characteristic polynomials of the random matrices in question, exploiting in particular their real-rootedness, interlacing, and invariance properties. Our analysis of the roots of these polynomials is based on finite analogues of tools from Free Probability Theory, in particular a finite-dimensional free convolution and corresponding R-transform inequality.

The Location Problem

Daniel Wulbert
University of California, San Diego, USA

The location problem follows an Approximation Theory paradigm: Identify a best approximation, $p(h)$ in P, to each, h, in a class, H, of continuous functions; but with the specifics chosen to model a physical setting.

An unmanned craft lands on an unobservable terrain (e.g., in a forest or on the backside of the moon). We wish to determine the location of the landing site. The craft can sample the altitude at the landing site and at several other spots (say at 100 meters east and at 100 meters west). However, the craft does not have a map of the altitudes of the terrain (i.e.,$h(x, y)$), to compare its data against. Instead we can have only a single function, $p(x, y)$, to simulate $h(x, y)$, and to which we compare our data.

The location problem is to find a function p, from a family of functions P ,that minimizes the error between the actual location of the craft and the computed location of the craft using the approximation p. That is, we wish to find the approximate, p, to minimize $\|p^{-1} - h^{-1}\|$.

The problem presents a rich theoretical setting with four fundamental elements to define (the metric, the domain of the inverse functions, and the families P and H of functions) and potentially has useful applications.

We present an introductory result in the basic setting of function defined on the real line. With either the uniform or L_1-norm, for every non-decreasing function h there is a unique increasing polynomial, p, of degree n, that minimizes $\|p^{-1} - h^{-1}\|$.

Symposium on 'Mathematics in Computer Science'

Organisers: *Srikanth Srinivasan* (Indian Institute of Technology, Mumbai, India) and *Madhu Sudan (Harvard University, USA)*

Lower Bounds for 2-Query LCCs Over Large Alphabet

Arnab Bhattacharyya
I.I.Sc, Bangalore, India

A locally correctable code (LCC) is an error correcting code that allows correction of an arbitrary coordinate of a corrupted codeword by querying only a few coordinates. We show that any 2-query LCC $\mathcal{C} : \{0,1\}^k \to \Sigma^n$ with *zero-error* that can correct a constant fraction of corrupted symbols must have $n \geq \exp(k/\log|\Sigma|)$. We say that an LCC is zero-error if there exists a non-adaptive corrector algorithm that succeeds with probability 1 when the input is an uncorrupted codeword. All known constructions of LCCs are zero-error.

Our result is tight upto constant factors in the exponent. The only previous lower bound on the length of 2-query LCCs over large alphabets was $\Omega((k/\log|\Sigma|)^2)$ due to Katz and Trevisan. Our bound implies that zero-error LCCs cannot yield 2-server private information retrieval (PIR) schemes with sub-polynomial communication. Since there exists a 2-server PIR scheme with sub-polynomial communication based on a zero-error 2-query locally decodable code (LDC), we also obtain a separation between LDCs and LCCs over large alphabet.

For our proof of the result, we need a new decomposition lemma for directed graphs that may be of independent interest. Given a directed graph G, our decomposition uses the directed version of Szemerédi regularity lemma due to Alon and Shapira to find an equipartition of almost all of G into subgraphs which are either edge-expanding or empty.

Joint work with Sivakanth Gopi (Princeton).

Submodular Function Minimization

Deeparnab Chakrabarty
Microsoft Research, Bangalore, India

Submodular function are set functions : $2^{[n]} \to R$ which capture the diminishing marginal returns dictum. More precisely, for any subset $S \subseteq T$ and $i \notin T$, the function satisfies

$$f(T \cup i) - f(T) \leq f(S \cup i) - f(S)$$

These functions arise in diverse fields including computer science, economics, information theory, and statistical inference. One important problem is that of submodular function minimization (SFM) which asks to find the subset $S^\star$ minimizing the value of f. A testament to the mathematical structure and beauty of this class of functions is that SFM can be done making only polynomially many queries to the function. This has been known since the late 80's, and yet the complexity of this problem has not been resolved.

In this survey-style talk I will focus on how *continuous optimization* techniques are useful for solving SFM, which seems to be a purely discrete optimization problem. These methods have led to the currently best known SFM algorithms. This talk will be self contained and no prior familiarity will be assumed.

Continuous Optimization: The "Right" Language for Graph Algorithms?

Aleksander Madry
Massachusetts Institute of Technology, USA

Traditionally, we view graphs as purely combinatorial objects and tend to design our graph algorithms to be combinatorial as well. In fact, in the context of algorithms, "combinatorial" became a synonym of "fast".

Recent work, however, shows that a number of such "inherently combinatorial" graph problems can be solved much faster using methods that are very "non-combinatorial". Specifically, by approaching these problems with tools and notions borrowed from linear algebra and, more broadly, from continuous optimization. A notable examples here are the recent lines of work on the maximum flow problem, the bipartite matching problem, and the shortest path problem in graphs with negative-length arcs.

This raises an intriguing question: Is continuous optimization a more suitable and principled optics for fast graph algorithms than the classic combinatorial view?

Taking Square Roots in a Finite Field

Rajat Mittal
Indian Institute of Technology, Kanpur, India

We study the problem of finding square roots deterministically in a finite field (F_{p^n}). This problem is equivalent to many problems like solving quadratic equations, finding quadratic non-residue and finding an irreducible of degree 2. We will look at different approaches towards finding square roots.

One of the well known approach for this problem is to give an upper bound on the least quadratic non-residue. We will look at Burgess' technique to give an $O(p^{1/4+\delta})$ bound for any $\delta > 0$. We will show that some parts of this technique can be generalized and will also discuss some of the possible applications.

This is based on joint work with Vishwas Bhargav, Nitin Saxena and Himanshu Shukla.

Lower Bounds on the Size of Semidefinite Programming Relaxations

Prasad Raghavendra
University of California, Berkeley, USA

We introduce a method for proving lower bounds on the efficacy of semidefinite programming (SDP) relaxations for combinatorial problems. In particular, we show that the cut, TSP, and stable set polytopes on n-vertex graphs are not the linear image of the feasible region of any SDP (i.e., any spectrahedron) of dimension less than 2^{n^δ}, for some constant $\delta > 0$. This result yields the first super-polynomial lower bounds on the semidefinite extension complexity of any explicit family of polytopes.

Our results follow from a general technique for proving lower bounds on the positive semidefinite rank of a matrix. To this end, we establish a close connection between arbitrary SDPs and those arising from the sum-of-squares SDP hierarchy. For approximating maximum constraint satisfaction problems, we prove that SDPs of polynomial-size are equivalent in power to those arising from degree-$O(1)$ sum-of-squares relaxations. This result implies, for instance, that no family of polynomial-size SDP relaxations can achieve better than a 7/8-approximation for MAX 3-SAT.

This talk is based on joint work with James R. Lee (University of Washington, Seattle) and David Steurer (Cornell University).

Improved Separations between Bounded-Depth Circuits and Formulas

Srikanth Srinivasan
Indian Institute of Technology, Mumbai, India

Boolean Circuits and Formulas are combinatorial models for computing functions of a finite number of input bits. While Boolean circuits can be thought of as modeling general Turing Machines (i.e. general computer programs) on a finite input length, formulas are combinatorially restricted and correspond to computer programs that can reuse the result of each computation only once.

A fundamental question in Circuit Complexity is that of whether a general Boolean circuit can be converted to a Boolean formula without significant blowup in size. It is a standard fact that any Boolean circuit of size s and depth d can be converted to a formula of size s^d. Recently, Rossman (FOCS 2015) showed that this was nearly tight for ^{0} circuits (made up of AND, OR and NOT gates) by showing that for constant d, there are functions

that have ^{0} circuits of size s and depth d but not ^{0} formulas of size less than $s^{\varepsilon d}$ and depth d for some $\varepsilon > 0$.

We strengthen this result by showing a lower bound for $^0[\oplus]$ formulas which can also perform sum modulo 2 (i.e. $\oplus$) computations. More precisely, we show that there are functions that have ^{0} circuits of size s and depth d but not $^0[\oplus]$ formulas of size less than $s^{\delta d}$ and depth d for some $\delta > 0$.

Joint with Ben Rossman (University of Toronto) and Rahul Santhanam (University of Oxford).

Bipartite Ramanujan Graphs of Every Degree

Nikhil Srivastava
University of California, Berkeley, USA

Expander graphs are very sparse graphs which are nonetheless very well-connected, in the sense that their adjacency matrices have large spectral gap. There is a limit to how large this gap can be for a d-regular graph, and graphs which achieve the limit are called Ramanujan graphs. A well-known number-theoretic construction of Lubotzky-Phillips-Sarnak and Margulis shows that infinite families of Ramanujan graphs exist for every d=p+1 where p is prime, leaving open the question of whether they exist for other degrees and whether they are inherently number-theoretic objects.

We prove that there exist infinite families of bipartite Ramanujan graphs of every degree bigger than 2. We do this by proving a variant of a conjecture of Bilu and Linial about the existence of good 2-covers of every graph. Our proofs are elementary and rely on simple facts from the theory of real stable polynomials. In particular, they do not rely on number theory, and the talk should be accessible to a broad audience.

(Joint work with Adam Marcus and Dan Spielman.)

Mathematics, Proofs and Computation

Madhu Sudan
Harvard University, USA

While it is well-understood that Proofs form the foundations of Mathematics, it is less well-known that Proofs and Computers are intimately related. Indeed a common perception is that the only link between Proofs and Computing is that sometimes computers can assist in the search for proofs. In this talk I will describe a more historically significant, and intrinsic, connection. Proofs are by definition "Computational Objects" - and to understand to the difference between a theorem and its proof, one needs to understand computational complexity of tasks - namely the number of steps on a computer needed to solve a given task. In this talk, I will talk about the historical role of proofs in computation, leading to the "prototype" of the modern computer in the 1930s, to the conception of the famous "Is

$P = NP$?" question in the 1970s and some modern variation like interactive proofs, zero-knowledge proofs and probabilistically checkable proofs. I will explain how at each stage the study of proofs has revolutionized our understanding of what computers can or can not do!

Symposium on 'Combinatorial Number Theory'

Organisers: *S. D. Adhikari* (Harish Chandra Research Institute, Allahabad, India) and *Alex Iosevich* (University of Rochester, New York, USA)

Weighted Zero-Sum Constants: A Survey

S. D. Adhikari
Harish Chandra Research Institute, Allahabad, India

We consider a particular weighted generalization of some classical zero-sum constants which have given rise to several conjectures and questions. Several people have worked on these; some of these questions have been answered and some applications of this weighted generalization have also been found.

The Distribution of the Number of Prime Factors with Restrictions- Variations of the Classical Theme

Krishnaswami Alladi
University of Florida, USA

The study of $\nu(n)$ the number of prime factors of n began with Hardy and Ramanujan in 1917 who showed that $\nu(n)$ has normal order $log\, log\, n$ regardless of whether the prime factors are counted singly or with multiplicity. Their ingenious proof of this utilized uniform upper bounds for $N_k(x)$, the number of integers up to x with $\nu(n) = k$. Two major results followed a few decades later - the Erdös-Kac theorem on the distribution more generally of additive functions, and the Sathe-Selberg theorems on the asymptotic behavior of $N_k(x)$ as k varies with x - a significant improvement of Landau's asymptotic estimate for $N_k(x)$ for fixed k. We shall consider the distribution of the number of prime factors by imposing certain restrictions - such as (i) requiring all prime factors of n to be $< y$ (the important case of smooth numbers), and (ii) considering only the prime factors $< y$, but for all integers. For (i), I showed in 1982 how an interesting variation of the classical theme with regard to the variance of $\nu(n)$ takes place when $\log x/log\, y$ is large, and this led to further work by Hildebrand, Tenenbaum, Hensley and myself on the Erdös-Kac Theorem for smooth numbers. Very recently, I noticed a surprising variation of the classical theme in the case (ii) with regard to the *local distribution*. Details of the asymptotic analysis of the local distribution in (ii) with

emphasis on uniformity in y is being carried out now by my PhD student Todd Molnar. Our approach involves the interplay of a variety of methods such as combinatorial counting, the Perron integral formula, the Selberg's method, Buchstab iteration, and difference-differential equations to achieve uniformity. Tenenbaum has indicated recently in communication that by a careful analysis involving the Selberg-Delange method, the error terms can be improved in certain crucial ranges.

The Number of Factorisations of an Integer

R. Balasubramanian
IMSc, Chennai, India

Perfect Powers in Products of Terms of Some Divisibility Sequences

Shanta Laishram
Indian Statistical Institute, Delhi, India

A *divisibility sequence* is an integer sequence $(a_n)_{n\in N}$ such that for all natural numbers m, n, if $m|n$ then $a_m|a_n$. A *strong divisibility sequence* is an integer sequence $(a_n)_{n\in N}$ such that for all natural numbers m, n, $\gcd(a_n, a_m) = a_{\gcd(m,n)}$. Fibonacci sequence and all other binary recurrence sequences and elliptic divisibility sequences are well-known examples of strong divisibility sequences. In this talk, I will discuss about the problem of finding perfect powers in the products of terms of some strong divisibility sequences like binary recurrence sequences and elliptic divisibility sequences.

Title: Every Finite Subset of an Abelian Group is an Asymptotic Approximate Group

Melvyn Nathanson
City University of New York, USA

If A is a nonempty subset of an additive abelian group G, then the *h-fold sumset* is

$$hA = \{x_1 + \cdots + x_h : x_i \in A_i \text{ for } i = 1, 2, \ldots, h\}.$$

We do not assume that A contains the identity, nor that A is symmetric, nor that A is finite. The set A is an *(r, ℓ)-approximate group in G* if there exists a subset X of G such that $|X| \leq \ell$ and $rA \subseteq XA$. The set A is an *asymptotic (r, ℓ)-approximate group* if the sumset hA is an (r, ℓ)-approximate group for all sufficiently large h. It is proved that every polytope in a real vector space is an asymptotic (r, ℓ)-approximate group, that every finite set of lattice points is an asymptotic (r, ℓ)-approximate group, and that every finite subset of every abelian group is an asymptotic (r, ℓ)-approximate group.

Certain Direct and Inverse Results in Additive Number Theory

Ram Krishna Pandey
Indian Institute of Technology, Roorkee, India

Let A be a finite subset of an abelian group G and $h, r \geq 1$ are integers. The generalized h-fold sumset, denoted by $h^{(r)}A$, is the sum of h elements of A, where each element appears in the sum can have at most r repetitions. Further, let $B = (\underbrace{a_0, \ldots, a_0}_{r \text{ copies}}, \underbrace{a_1, \ldots, a_1}_{r \text{ copies}}, \ldots, \underbrace{a_{k-1}, \ldots, a_{k-1}}_{r \text{ copies}})$ be a finite sequence of integers with k distinct terms, $a_0 < a_1 < \cdots < a_{k-1}$. The sum of all the terms of a subsequence of length at least one of the sequence B is said to be the subsequence sum of B. The set of all subsequence sums of B is denoted by $S(r, B)$. In this talk, we present some direct and inverse results for $|h^{(r)}A|$ and $|S(r, B)|$.

A Problem of A. Sarközy on Coloured Versions of the Lagrange and Vinogradov Theorems

D. S. Ramana
Harish Chandra Research Institute, Allahabad, India

In this talk we describe some progress on the following problem of A. Sárközy. For any integer $K \geq 1$, let $s(K)$ be the smallest integer such that when the set of squares is coloured in one of K colours, every sufficiently large integer can be written as a sum of at most $s(K)$ squares. Also, let $t(K)$ be the corresponding integer in the analogous context for the set of primes. The problem is to find optimal upper bounds for $s(K)$ and $t(K)$ in terms of K.

On Borel's Conjecture Related to Normal Numbers

R. Thangadurai
Harish Chandra Research Institute, Allahabad, India

In 1909, E. Borel proved that almost all real numbers, in the sense of Lebesgue measure, are normal numbers to the base b for all integers $b \geq 2$. He conjectured that all algebraic irrational numbers are normal to base b for all integers $b \geq 2$. In 1978, Mahler proved that if α is an irrational number written in base b and $B = b_0 \ldots b_{n-1}$ is a given block of digits in base b for some integer $n \geq 1$, then there exists integer X such that the given block B appears in the base b representation of the fractional part of $X\alpha$ infinitely often. We shall talk about the recent work on a conditional quantitative version of Mahler's Theorem related to Borel's conjecture.

Symposium on 'Commutative Algebra'

Organisers: *Satya Mandal*, University of Kansas, USA
and *Jugal Verma, Indian Institute of Technology, Mumbai, India*

Homological Algebra of Powers of Edge Ideals

Arindam Banerjee
Purdue University, West Lafayette, USA

In this talk we shall discuss the relation between homological invariants of powers of edge ideals and the combinatorics of the underlying finite simple graphs. Some recent progress and open questions for future research will be discussed.

Castelnuovo-Mumford Regularity of Binomial Edge Ideals of Certain Block Graphs and Trees

A. V. Jayanthan
Indian Institute of Technology, Chennai, India

The connection between the combiatorial invariants of a graph and algebraic invariants of the corresponding edge ideals has been a theme of research for the past decade or two. It is conjectured by Kiani and Madani that the Castelnuovo-Mumford regularity of the binomial edge ideal of a graph is bounded above by the number of maximal cliques in the graph. This has been proved for generalized block graphs. We obtain some finer bounds for certain special subclasses of block graphs. We use this to study the regularity of trees. We prove that the regularity of a tree is bounded below by one more than the number of internal vertices. We characterize the minimal regularity in terms of the existence of "Jewel graph" as a subgraph of the given tree.

Existence of Unimodular Elements in a Projective Module over Polynomial Rings

Manoj Keshari
Indian Institute of Technology, Mumbai, India

Let R be a commutative Noetherian ring of dimension d and $A = R[X_1, \ldots, X_n]$ be a polynomial ring in n variables over R. Let P be a finitely generated projective A-module of rank d. Let $f \in A$ be a monic polynomial in the variable X_n. If P_f has a unimodular element, then P has a unimodular element. In other words, $P_f \simeq Q \oplus A_f$ implies $P \simeq Q' \oplus A$.

When $n = 1$, this result is due to Roitman when R is a local ring and due to Bhatwadekar-Sridharan for general R. This is a joint work with Md. Ali Zinna.

Cohomology of Normalized Blow-Ups

Manoj Kummini
Chennai Mathematical Institute, Chennai, India

We will discuss some results on normalized blow-ups inthree-dimensional noetherian normal domains.

Commutative Algebra and Algebraic K-Theory

Satya Mandal
University of Kansas, Lawrence, USA

Before the work of Quillen (1972), Higher Algebraic K-Theory was considered as a part of Commutative Algebra (Rings and Modules). In this talk we would discuss this author's recent efforts to bridge this artificial (tantalizing) gap between Commutative Algebra and Algebraic K-Theory, which developed during this last forty plus years. During the same period, Algebraic K-Theory also has progressed a long distance. Advent of negative -theory is among the greatest milestones. For some further flavor, assume X is a quasi projective scheme. Given a chain complex map $\nu_\bullet : \mathcal{L}_\bullet \mathcal{G}_\bullet$ between two complexes $\mathcal{L}_\bullet$, $\mathcal{G}_\bullet$, of coherent (or locally free) sheaves on X, one complex can be viewed as an approximation to the other. In general, constructing such approximations would be challenging. In the affine case $X = Spec(A)$, such amap was constructed byHans-Bjørn Foxby (unpublished), using Koszul complexes. We implement this constructionto quasi projective schemes. This can be considered as a "graded version" of Foxby's construction. The main point of this talk is, how we apply this approximating tool to (negative) -Theory and Grothendieck Witt (GW)-Theory.

Defining Ideal of the Rees Algebra of Ideals

Vivek Mukundan
Tata Institute of Fundamental Research, Mumbai, India

Let $R = k[x_1, ..., x_n]$ and I be a grade two perfect ideal in R such that the number of generator of I is $n+1$. Further we assume that the ideal I satisfies a condition which forces it to be of linear type in the punctured spectrum. Under these conditions we give new methods to find a generating set for the defining ideal of the Rees algebra. Additionally, studying these equations gives us a characterization for a morphism $\Phi : P_k^{n-1} - - > P_k^n$, to be birational onto its image. We will present the characterization of the morphism Φ being birational in terms of differential maps of a free resolution of the symmetric algebra of I. Our criteria is obtained by studying the degrees of the defining ideal of the special fiber ring $F(I)$.

Symmetries and Connected Components of the AR-Quiver

Tony Puthenpurakal
Indian Institute of Technology, Mumbai, India

Let (A, m) be a commutative complete equicharacteristic Gorenstein isolated singularity of dimension d with $k = A/m$ algebraically closed. Let $\Gamma(A)$ be the AR (Auslander-Reiten) quiver of A.Let $\mathcal{P}$ be a property of maximal Cohen-Macaulay A-modules. We show that some naturally defined properties $\mathcal{P}$ define a union of connected componentsof $\Gamma(A)$. So in this case if there is a maximal Cohen-Macaulay module satisfying $\mathcal{P}$ and if A is not of finite representation type then there exists a family $\{M_n\}_{n\geq 1}$ of maximal Cohen-Macaulay indecomposable modules satisfying $\mathcal{P}$ with multiplicity $e(M_n) > n$. Let $\underline{\Gamma}(A)$ be the stable quiver. We show that there are many symmetries in $\underline{\Gamma}(A)$. Furthermore $\underline{\Gamma}(A)$ is isomorphic to its reverse graph. As an application we show that if (A, m) is a two dimensional Gorenstein isolated singularity with multiplicity $e(A) \geq 3$ then for all $n \geq 1$ there exists an indecomposable self-dual maximal Cohen-Macaulay A-module of rank n.

The Quillen-Suslin Local Global Principle and Horrock's Monic Inversion Principle

Ravi A. Rao
Tata Institute of Fundamental Research, Mumbai, India

Quillen solved the Serre's problem on freeness of Projective modules over a polynomial extension over a field by using a Local-Global argument and the Monic Inversion Principle of Horrock's. We show that these two Principles are equivalent. This is a joint work with Sunil Yadav.

Intersection Multiplicity Over a Two-Dimensional Base

Chris Skalit
University of Illinois Chicago, USA

Let A be a local ring, essentially smooth over a regular, two-dimensional base. We show that the intersection multiplicity - as defined by Serre's Tor formula - of two complimentary-dimensional A-modules is always positive. We in turn use this result to investigate the geometry of intersections on arithmetic schemes. Inparticular, we attempt to give a purely numerical criterion for transversality.

Gorenstein Monomial Curves

Hema Srinivasan
University of Missouri, Columbia, USA

This is a joint project with Philippe Gimenez. Let k be an arbitrary field. We strengthen the criterion of Brezinsky for Gorenstein monomial curves and use it to construct a class of monomial Gorenstein curves. In particular, we show that if a sequence of relatively prime positive integers $\mathbf{a} = (a_1, a_2, a_3, a_4)$ defines a Gorenstein non complete intersection monomial curve $\mathcal{C}(\mathbf{a})$ inA_k^4, then there exist two vectors $\mathbf{u}$ and $\mathbf{v}$ such that$\mathcal{C}(\mathbf{a} + t\mathbf{u})$ and $\mathcal{C}(\mathbf{a} + t\mathbf{v})$ are also Gorenstein non complete intersection affine monomial curvesfor almost all $t \geq 0$. We define the notion of a pseudo Gorenstein matrix of size 4 and show that associated to a pseudo Gorenstein matrix of size 4, there is a Gorenstein ideal which becomes the ideal of a monomial prime if it is a prime ideal and we construct explicit resolutions for these ideals. We will discuss some plausible generalizations of this notion to matrices of higher size.

Hilbert-Kunz Density Function and Hilbert-Kunz Multiplicity

Vijaylaxmi Trivedi
Tata Institute of Fundamental Research, Mumbai, India

For a pair (R, I), where R is a standard graded ring R and I is a graded ideal of finite colength, we introduce a new invariant, the *Hilbert-Kunz density function*,which is a limit of a uniformly convergent sequence ofreal valuedcompactly supported, piecewise linear and continuous functions.We express the Hilbert-Kunz multiplicity, $e_{HK}(R, I)$ as an integral of this function.

We show that this function (unlike e_{HK}) satisfies a multiplication formula for the Segre product of rings. As a consequence someknown result for e_{HK} of rings hold for e_{HK} of their Segre products.

We state (if time permits) a few other applications of this function, like asymptotic behaviour of $e_{HK}(R, I^k)$ as $k \to \infty$, e_{HK} of the Segre product of rings and a possibleapproach for e_{HK} in characteristic 0.

Postulations and Reduction Vectors of Multi-Grades Hilbert Functions

JK Verma
Indian Institute of Technology, Mumbai, India

We study relationship between postulation and reduction vectors of Hilbert functions of admissible multigrades filtrations $\mathcal{F} = F(n)_{n \in Z^n}$ of idealsin Cohen-Macaulay local ringsofdimension atmost two. This is enabled by a suitable generalisation of the Kirby-Mehran Complex. An analysis of its homology leads to an analogue of Huneke's fundamental Lemma which plays a crucial role in our investigations. We also clarify the relationship between Cohen-Macaulay property of the multigraded Rees algebra of $\mathcal{F}$ and reduction vectors with respect to complete reductions of F.

Symposium on "Differential Geometry and Teichmueller Theory"

Organisers: *Mahan Mj* (Tata Institute of Fundamental Research, Mumbai, India),
Krishnendu Gongopadhyay (IISER, Mohali, India)
and *Kenneth Bromberg*, (University of Utah, USA)

An ODE Related to the Ricci

Atreyee Bhattacharya
RK-MVU, Kolkata, India

The Ricci flow, a geometric evolution equation of a Riemannian manifold, introduced by Richard Hamilton, is often useful in understanding geometric and topological properties of the underlying manifold. In the recent past, Ricci flow and associated techniques have played pivotal roles in solving some long-standing open problems in Geometry-Topology (e.g., the Poincaré conjecture, the differentiable sphere theorem, etc.). In this talk we discuss about an ODE closely associated to the evolution of curvature along the Ricci flow. Hamilton and later, Böhm and Wilking introduced algebraic techniques to understand curvature conditions that remain unchanged under Ricci flow, in terms of 'invariant sets' of this ODE. We try to understand the 'fixed directions' of this ODE and analyse the behaviour of the ODE near its fixed directions. In particular, these fixed directions include Riemannian curvature operators of irreducible symmetric spaces of compact type. We also show the existence of solution curves to this ODE connecting curvature operators of some symmetric spaces.

Moebius Maps and Rigidity Problems for Negatively Curved Spaces

Kingshook Biswas
RK-MVU, Kolkata, India

We discuss rigidity problems for negatively curved spaces, including the marked length spectrum and geodesic conjugacy problems for closed negatively curved manifolds. These problems motivate the question which is the main focus of the talk: does a Moebius map between the boundaries of two CAT(-1) spaces extend to an isometry between the spaces? We discuss some partial results, including the fact that if the spaces are proper and geodesically complete then any Moenius map extends to a $(1, \log 2)$-quasi-isometry.

Deformations of Convex Real Projective Structures on Orbifolds

Suhyoung Choi
KAIST, South Korea

In this survey, we study representations of finitely generated groups into Lie groups, focusing on the holonomy representations of convex real projective structures on closed manifolds and orbifolds, with an excursion on projective structures on surfaces. We survey the basics of the theory of character varieties, geometric structures on orbifolds and Hilbert geometry. The main examples of finitely generated groups for us will be Fuchsian groups, 3-manifold groups and Coxeter groups. (This is a joint work with Gye-seon Lee and Ludovic Marquis.)

Discrete Groups in Lorentzian Geometry

Todd Drumm
Howard University, USA

In the 1980's, Margulis, was the first to show that free discrete groups can act properly on $R^(2,1)$, the flat Lorentzian 3-space. The resulting "Margulis space-times" have been studied and classified. We will look at these discrete group actions via "Crooked Planes" (Charette-D-Goldman) and "Strip Deformations" (Danciger-Gueritaud-Kassel).

Harmonic Maps and Teichmueller Spaces of Crowned Hyperbolic Surfaces

Subhojoy Gupta
IISc, Bangalore, India

A crowned hyperbolic surface has "bordered cusps", and arises on uniformizing a compact Riemann surface with distinguished points on its boundary components. I shall describe work in progress that uses meromorphic quadratic differentials with higher order poles to parametrize the Teichmüller space of such surfaces. This extends Wolf's parametrization of the Teichmüller space of a closed surface using holomorphic quadratic differentials. Our proof involves showing the existence of a harmonic map from a punctured Riemann surface to a crowned hyperbolic surface, and determining the relation between the asymptotic behavior at the punctures and the principal parts of the meromorphic Hopf differential.

Taut Foliations in 3-Manifolds

Tejas Kalelkar
IISER, Pune, India

Every 3-manifold has a foliation by 2-dimensional manifolds (called leaves). A foliation is called taut if there exists a simple closed curve in the manifold that intersects each leaf of the foliation transversally. A surface bundle over a circle is the simplest example of a 3-manifold with a taut foliation. Every 3-manifold can be obtained from a surface bundle by Dehn

filling the boundary components (with solid tori). We have proved that the fiber structure of a surface bundle can be perturbed to taut foliations realizing all rational boundary slopes in a neighbourhood of the the boundary slopes the fiber. This allowed us to prove that 3-manifolds obtained by Dehn-filling a surface-bundle along slopes sufficiently close to the slopes of the fiber produce closed 3-manifolds that contain taut foliations. In other words, closed 3-manifolds that are ÔnearÕ closed surface bundles (in terms of the Dehn-filling slopes) also have taut foliations.

On Local Minimizing Property of L_p-Norms of Riemannian Curvature Tensor

Soma Maity
RK-MVU, Kolkata, India

Let M be a closed smooth manifold. For any $p \in [2, \infty)$, L_p of Riemannian curvature denoted by R_p is a real valued function defined on the space of Riemannian metrics. Irreducible locally symmetric spaces are critical metrics for R_p. I will discuss stability and local minimizing properties of R_p at those critical points.

Polyhedra Inscribed in Quadrics and Their Geometry

Sara Maloni
Brown University, USA

In 1832 Steiner asked for a characterization of polyhedra which can be inscribed in quadrics. In 1992 Rivin answered in the case of the sphere, using hyperbolic geometry. In this talk, I will describe the complete answer to Steiner's question, which involves the study of interesting analogues of hyperbolic geometry including anti de Sitter geometry. Time permitting, we will also discuss future directions in the study of convex hyperbolic and anti de Sitter manifolds. (This is joint work with J. Danciger and J.-M. Schlenker.)

Extremal Length Geometry on Teichmuller Space

Hideki Miyachi
Osaka University, Japan

In this talk, I will survey my results on Extremal length geometry of Teichmuller space. I will explain a unification of extremal length geometry in Thurston theory. If time permits, I will discuss a recent progress of my research for connecting between Topological aspect and Complex analytical aspect on Teichmuller theory.

On the Symplectic Representations of Finite Order Mapping Classes

Kashyap Rajeevasarathy
IISER, Bhopal, India

Let $\mathrm{Mod}(S_g)$ be the mapping class group of the closed orientable surface S_g of genus g. In this talk, we give an algorithm to determine up to conjugacy, the symplectic representation of a finite order element in $\mathrm{Mod}(S_g)$. We apply this algorithm to compute nontrivial roots of elementary matrices in the integral symplectic group.

Graphs of Groups and a Limit Set Intersection Theorem

Pranab Sardar
IISER, Mohali, India

Given a hyperbolic group G we say that a collection C of subgroups of G satisfies the limit set intersection property if for any $H, K \in C$ we have $\Lambda(H)\Lambda(K) = \Lambda(HK)$. If a hyperbolic group G admits a decomposition into a graph of hyperbolic groups with *qi* embedded condition then we show that the collection of conjugates of the vertex groups and the edge groups satisfy the limit set intersection property.

Discrete Group Representations in $PSL(3, C)$

Jose Seade
Universidad Nacional Autonoma de Mexico, Mexico

We will discuss some old and new facts about discrete group actions on the complex projective plane.

Hyperbolic Jigsaws and Families of Pseudomodular Groups

Ser Peow Tan
National University of Singapore, Singapore

A pseudomodular group is a Fuchsian group which is not commensurable with the modular group but which has cusp set all of the rationals. We show that there are infinitely many commensurability classes of pseudomodular groups, thus answering a question raised by Long and Reid. We do this by introducing a general construction of Fuchsian groups obtained by gluing together marked ideal triangular tiles, which we call hyperbolic jigsaw groups. This is joint work with Beicheng Lou.

Symposium on 'Ergodic Theory'

Organiser: *Riddhi Shah* (JNU, New Delhi, India)

β -Transformation on an Interval with Hole

Nikita Agarwal
IISER Bhopal, India

Let T_β be the expanding map of $[0,1]$ defined by $T_\beta(x) = \beta x \mod 1$, where β is an integer atleast 2. Given $0 \leq a < b \leq 1$, let $\mathcal{W}_\beta(a,b) = \{x \in [0,1] \mid T_\beta^n x \notin (a,b), n \geq 0\}$ be the maximal T-invariant subset of $[0,1] \setminus (a,b)$. We characterize the intervals (a,b) for which the Hausdorff dimension of $\mathcal{W}_\beta(a,b)$ is positive. We will also present results for product of circle maps with holes.

Studying Values of Binary Quadratic Forms Through Dynamics

S. G. Dani
Indian Institute of Technology, Mumbai, India

In this talk, we discuss the set of values of binary quadratic forms, with real or complex coefficients, when the variables are assigned numbers from certain discrete subrings. Conditions for values to be dense, or to stay away from 0, will be described, in terms of continued fraction expansions with entries in the discrete subring. The techniques depend on the study of certain flows on homogeneous spaces.

Effective Versions of Oppenheim's Conjecture

Anish Ghosh
Tata Institute of Fundamental Research, Mumbai, India

Oppenheim's long standing conjecture on values of quadratic forms at integer points was resolved by G. Margulis using an observation of Raghunathan connecting the problem to dynamics on the space of lattices. Subsequent important work was carried out by Dani-Margulis and Eskin-Margulis-Mozes among others. However, the problem of obtaining an effective form of Margulis' theorem has remained largely open. I will explain what this means and report on several recent developments in this direction due to Lindenstrauss-Margulis, Ghosh-Gorodnik-Nevo, Bourgain and Ghosh-Kelmer.

Finite Covolume Subgroups are Cocompact

C.R.E. Raja
Indian Statistical Institute, Bangalore, India

We describe groups for which any finite covolume subgroup is cocompact. We also discuss classical results of Mostow, Wang and the recent developments in this direction.

Expansive Automorphisms of Locally Compact Groups

Riddhi Shah
JNU, New Delhi, India

We classify connected groups admitting an expansive automorphism. We discuss if the expansivity of an automorphism carries over to the quotients by invariant normal subgroups. We also discuss properties of various groups associated with an automorphism and relate them to expansivity and/or distality of the automorphism.

Symposium on 'History of Mathematics'

Organisers: *S. G. Dani* (Indian Institute of Technology, Mumbai, India) and *Kim Plofker* (Union College, Schenectady, New York, USA)

Onset of Modern Mathematics in India, and its Early Years

S. G. Dani
Indian Institute of Technology, Mumbai, India

In this talk I will trace the development of modern mathematics in India, starting from around the middle of the nineteenth century, until the middle of the twentieth century. Personalities, events, and the general ethos of the period from the point of view of mathematics will be the focus of the talk.

The Solution of the Bahā al-dīn al-'Āmilī Problem - Elliptic Curves to the Rescue!

Lawrence D'Antonio
Ramapo College of New Jersey, USA

Fermat's Last Theorem was not the only Diophantine problem whose solution required the use of elliptic curves. The Islamic mathematician Bahā al-dīn al-'Āmilī, in his early 17th century work, the *Khulāṣāt al-Ḥisāb*, (Essence of Reckoning), discussed seven unsolved problems in algebra. One of the problems was, in fact, Fermat's Last Theorem in the cubic case. Another problem, the seventh, was to find rational solutions for the pair of equations:

$$x^2 + x + 2 = y^2, \quad x^2 - x - 2 = z^2.$$

In this talk we trace the history of the problem, first considering the origins of this problem and its relationship to the questions about congruent numbers. Next, the first systematic attempt at a solution, using the chord and tangent method, was done by Lucas in 1877. Finally, Horst Zimmer found the complete solution to the problem in 1983. Zimmer transforms rational solutions of the Bahā al-dīn al-'Āmilī problem into rational points on a certain elliptic curve, and then gives a complete description of the group of rational points on that curve.

Spherical Geometry, from the Work of Menelaus of Alexandria

Athanase Papadopoulos
University of Strasbourg and and Centre National de la Recherche Scientifique, France

I will present some theorems in spherical geometry from the work of Menelaus of Alexandria (1st c. A.D.) and compare them to some theorems in hyperbolic geometry.

Transmission and Evolution of Trigonometric Approximations in 18th-Century India

Kim Plofker
Union College, Schenectady, New York, USA

The well-known "feedback loop" of trigonometry of sines from its Indian origins to the Islamic world and back in the early modern period includes many interesting and understudied developments. This talk examines a Sanskrit adaptation and refinement of a medieval method for sine approximation, apparently from the court of Jai Singh in the early 18th century.

Developments In Tala-Prastara (Combinatorics of Rhythmic Patterns) After Sangitaratnakara (c.1225)

M.D. Srinivas
Centre for Policy Studies, Chennai, India

Six combinatorial tools (called *pratyayas*) have been in systematic use in India for the study of patterns arising in prosody, music etc., and these go back least to *Chandas-sastra*, the classic text on Sanskrit prosody by Pingala (c. 300 BCE). Three among these, *prastara* (an enumeration rule for generating all the possible patterns of a given class as a sequence of rows), *uddishta* (the process for finding, for any given metrical pattern, the corresponding row number in the enumeration) and *nashta* (the converse of *uddishta*) are found in the Bharata's *Natyasastra*, in the chapter where prosody is discussed. The notion of *pratyayas* was perhaps discussed in other ancient texts of music also. However, the first extant text on music where the *pratyayas* are systematically dealt with, both in connection with patterns of musical phrases (*tanas*) and patterns of musical rhythms (*talas*), is *Sangitaratnakara* (c. 1225) of Sarngadeva.

Tala-prastara is dealt with at length in the sixth chapter of *Sangitaratnakara*. It is in fact a generalisation of the theory of *pratyayas* for moric metres or *matra-vrttas*, where the short syllable (*laghu*) is taken to be of one *matra* (metrical time unit) and the long syllable (*guru*) is taken to be of two *matras*. *Sangitaratnakara* considers rhythmic patterns (tala) made up of the *talangas* (rhythmic elements), *druta* (of one time unit) and *laghu*, *guru* and *pluta*, which are of 2, 4 and 6 durations respectively, of that of *druta*. *Sangitaratnakara* first presents a systematic method of enumerating all the *talas* of a given time duration in a *prastara*, and follows this up with a complete mathematical theory of *pratyayas*. An interesting feature of *tala-prastara* is that the total number of patterns of duration n, S_n (n-th Sarngadeva number), satisfies the recurrence relation

$$S_n = S_{n-1} + S_{n-2} + S_{n-4} + S_{n-6}$$

The *tala-prastara* of *Sangitaratnakara* was generalised by Bhandaru Lakshminarayana in his *Sangita-suryodaya* (c.1520) and Poluri Govindakavi in his Telugu work *Tala-dasaprana-pradipika* (c. 1650). Following the then developing tradition in Carnatic music, these works started with *anudruta* as the basic rhythmic element; the time duration of *druta* would be twice that of the *anudruta*; and allowance was made for five different types of *laghus* namely *tisra, chaturasra, khanda, misra and sankirna* with the time durations of 3, 4, 5, 7, and 9 *anudrutas*, respectively. The time durations of *guru* and *pluta* were, as before, twice and thrice the duration of *laghu*, respectively. The combinatorics of rhythmic patterns with these five basic elements (*pancanga-tala-prastara*) is also discussed in some of the later works and the tradition continued well into the twentieth century as may be seen in the famous Telugu treatise *Gayakalocanam* (c. 1902) of Tacchur Brothers. In the *pancanga-prastara*, the total number S_n, of patterns of duration n, satisfies the recurrence relation

$$S_n = S_{n-1} + S_{n-2} + S_{n-\alpha} + S_{n-2\alpha} + S_{n-3\alpha}$$

where α can take the values $3, 4, 5, 7, 9$.

In our presentation we shall briefly summarise the theory of *tala-prastara* as discussed in

Sangitaratnakara and follow it up with the theory of *panchanga-tala-prastara* as discussed in the later works. We shall also indicate how the theory of *nashta* and *uddishta* processes presupposes a general representation of natural numbers as sums of Sarngadeva-numbers or the generalized-Sarngadeva-numbers.

The Irreducibility of The Cyclotomic Polynomials

Steve Weintraub
Lehigh University, Pennsylvania, USA

The irreducibility of the cyclotomic polynomials is a basic result in algebra/number theory. There are simple and well-known proofs in the prime case due to Schoenemann/Eisenstein and in the general case due to Dedekind. But these were not the original proofs. The original proof in the prime case is due to Gauss, and in the general case to Kronecker. These are both very involved proofs. We will describe the history of these results and explicate Kronecker's proof.

Symposium on "Logic"

Organisers: *Sujata Ghosh* (Indian Statistical Institute, Chennai, India) and *Rohit Parikh* (City University of New York, New York, USA)

Knowing the Model

Sergei Artemov
Computer Science, CUNY Graduate Center, 365 Fifth Ave, New York, USA

Epistemic modal logic normally views an epistemic situation as a Kripke model [2, 3, 4]. We consider a more basic approach: to view an epistemic situation as a set W of possible states/worlds – maximal consistent sets of propositions – with conventional accessibility relations determined by W. We find that in many epistemic situations, W is not a Kripke model: a necessary and sufficient condition for W to be a Kripke model is the so-called *fully explanatory property* – a propositional form of *common knowledge of the model* – which has been a hidden (and overlooked) assumption in epistemic modal logic.

We sketch a theory that describes epistemic models in their generality [1]. We argue for conceptual and practical value of new models, specifically for representing partial knowledge, asymmetric knowledge, and awareness.

References

[1] S. Artemov, *Knowing the Model* ***ArXiv Preprint***, arXiv:1610.04955 (2016).

[2] R. Fagin, J. Halpern, Y. Moses, and M. Vardi, ***Reasoning About Knowledge***, MIT Press, 1995.

[3] J.-J. Ch. Meyer and W. van der Hoek, ***Epistemic Logic for AI and Computer Science***, Cambridge, 1995.

[4] T. Williamson, *A note on Gettier cases in epistemic logic* ***Philosophical Studies***, vol. 172 (2015), no. 1, pp. 129–140.

Logics from Rough Set Theory

Mohua Banerjee
Indian Institute of Technology, Kanpur, India

Rough set theory hinges on the simple notion of an 'approximation space', considered by Pawlak to be a set (domain) with an equivalence (indiscernibility) relation on it. Concepts, represented as subsets of the domain, are described by means of their 'lower' and 'upper approximations' with respect to the approximation space. Information systems or attribute-value representation models, are 'practical' sources for approximation spaces. In the talk, we sketch the propositional logics that rough set theory gives rise to, including logics of information systems. Modal operators play an important role in the narrative.

Paradoxes and Games

Can Baskent
University of Bath, UK

In this talk, I will discuss what game theory can learn from non-classical logics. I will examine this idea by considering some paradoxes of epistemic game theory. First, I will briefly present an overview of a self-referential paradox in games that is similar to Liar's Paradox. Then, I will discuss at length how we can generate a non-self-referential paradox. I will present the formal results and their game theoretical implications. I will conclude by suggesting a connection between games and non-classical logics.

Pairs of Algebras and Logic

Mihir Chakraborty
Jadavpur University and Sivatosh Mookerjee Science Centre, India

Algebraic semantics for a logic usually consists of an algebraic structure , in fact, a class of algebraic structures relative to which the particular logic becomes sound and complete. Our recent studies reveal that in reality two or three algebraic structures get involved in this kind of semantics. This revelation leads to a general scheme of producing various logics depending on various pairs of algebras. In my talk , I will present the scheme and instantiate with several examples.

Epistemic Gossip Protocols

Hans van Ditmarsch
LORIA, Nancy, France

A well-studied phenomenon in network theory since the 1970s are optimal schedules to distribute information by one-to-one communication between nodes. One can take these communicative actions to be telephone calls, and protocols to spread information this way are known as gossip protocols or epidemic protocols. Statistical approaches to gossip have taken a large flight since then, witness for example the survey "Epidemic Information Dissemination in Distributed Systems" by Eugster et al. ($IEEEComputer, 2004$). It is typical to assume a global scheduler who executes a possibly non-deterministic or randomized protocol. A departure from this methodology is to investigate epistemic gossip protocols, where an agent (node) will call another agent not because it is so instructed by a scheduler, but based on its knowledge or ignorance of the distribution of secrets over the network and of other agents knowledge or ignorance of that. Such protocols are distributed and do not need a central scheduler. This comes at a cost: they may take longer to terminate than non-epistemic, globally scheduled, protocols. A number of works have appeared over the past years ($Aptetal., Attamahetal., vanDitmarschetal., vanEijcketal., HerzigandMaffre$) of which we present a survey, including open problems yet to be solved by the community.

Logics for Probabilistic Learning

Soroush Rafiee Rad
University of Amsterdam, Netherlands

In this talk we explore an epistemic logic for probabilistic inference. In particular, we will investigate the dynamics of probabilistic belief, arising from both direct observations as well as receiving higher order information. We will look at different probabilistic inference processes that capture different approaches to revising rational belief on the basis of probabilistic evidence and will especially focus on the logic capturing the Objective Bayesian account and will briefly discuss its long-term behaviour for iterated belief revision.

Logical Dynamics in Large Games

R. Ramanujam
IMSc, Chennai, India

How would you strategize in a game with say, 50 players ? If the game were repeated many times, and you saw that your neighbour was doing well in several previous rounds, would you be tempted to imitate the neighbour in the next round ? Would that be *rational* on your part ?

In games with a large number of players, outcomes are associated not with the actual tuple of strategies chosen by players but with the distribution of what fraction of players choose which move. The pattern of reasoning in such games is different from those in which all players know each others' types. We discuss Nash equilibria, and some logical / automata theoretic formulations of stability in such games.

On A Finitary Analogue of the Downward Löwenheim-Skolem Property

Abhisekh Sankaran
Indian Institute of Technology, Mumbai, India

We present a new logic based combinatorial property of finite structures, that can be regarded as a finitary analogue of the classical downward Löwenheim-Skolem property from model theory. This property, that we call the *Equivalent Bounded Substructure Property*, abbreviated , intuitively states that a large structure contains a small "logically similar" substructure. It turns out that this simply stated property is enjoyed by a variety of classes of interest in computer science: examples include classes defined using posets, such as words, trees (unordered, ordered or ranked) and nested words, and classes of graphs, such as cographs, graph classes of bounded tree-depth, those of bounded shrub-depth, m-partite cographs, and more generally, graph classes that are well-quasi-ordered under the (isomorphic) embedding relation. Further, remains preserved under various well-studied operations, such as complementation, transpose, the line-graph operation, disjoint union, join, series and parallel connects, and many products including the cartesian and tensor products. This enables constructing a wide spectrum of interesting classes that satisfy . We present applications of our investigations into , to complexity theory and graph minor theory: for the former, we show that many NP-complete problems (such as 3-colorability) become polynomial time solvable over several classes, and for the latter, we show that every finite graph has a small logically similar minor.

An Application of Descriptive Set Theory to the Pull-Back of Transition Probabilities

S.M. Srivastava
Indian Statistical Institute, Kolkata, India

A **transition probability** $P : X \mapsto Y$ is a map $P : X \times \mathcal{B} \to [0,1]$ satisfying the following two conditions:

1. For every $B \in \mathcal{B}$, $x \to P(x,B)$ is $\mathcal{A}$-measurable.
2. For every $x \in X$, $P(x,\cdot)$ is a probability measure on $\mathcal{B}$.

The category of transition probabilities has its objects transition probabilities $P : (X,\mathcal{X}) \mapsto (Y,\mathcal{Y})$, where $(X,\mathcal{X})$ and $(Y,\mathcal{Y})$ are measurable spaces and morphism $\Phi = (f,g) : P \mapsto Q$, where $P : (X,\mathcal{X}) \mapsto (Y,\mathcal{Y})$ and $Q : (A,\mathcal{A}) \mapsto (B,\mathcal{B})$ are transition probabilities, is a pair of measurable **surjections** $f : X \to A$ and $g : Y \to B$ such that for every $x \in X$ and $E \in \mathcal{B}$,

$$Q(f(x),E) = P(x,g^{-1}(E)).$$

Let $P_1 : X_1 \mapsto Y_1$ and $P_2 : X_2 \mapsto Y_2$ be transition probabilities. A pull-back of P_1 and P_2 consists of a transition probability $Q : A \mapsto B$ and morphisms $\Phi_1 : Q \to P_1$ and $\Phi_2 : Q \to P_2$. We prove the following result.

Theorem. *Let $P_1 : X_1 \mapsto Y_1$, $P_2 : X_2 \mapsto Y_2$, $P : X \mapsto Y$ be transition probabilities with X_1, Y_1, X_2, Y_2 Polish and X, Y second countable metrizable. Suppose there exist morphisms $\Phi_i = (f_i, g_i) : P_i \mapsto P$, $i = 1,2$. Then there exists a pull-back $Q : A \mapsto B$ of P_1 and P_2 with A, B Polish.*

This is a joint work with E. E. Doberkat.

Symposium on 'Number Theory: Automorphic Forms'

Organisers: *Dipendra Prasad* (Tata Institute of Fundamental Research, Mumbai, India) and *Kartik Prasanna* (University of Michigan, Ann Arbor, USA)

Symplectic Models for Unitary Groups

Sarah Dijols
Aix Marseille University, France

In analogy with the study of representations of $\mathrm{GL}_{2n}(F)$ distinguished by $\mathrm{Sp}_{2n}(F)$, where F is a local field, we have studied representations of $\mathrm{U}_{2n}(F)$ distinguished by $\mathrm{Sp}_{2n}(F)$. We have only considered quasi-split unitary groups as they are the only one containing $\mathrm{Sp}_{2n}(F)$. We will give elements of the proof that there are no cuspidal representations of $\mathrm{U}_{2n}(F)$ distinguished by $\mathrm{Sp}_{2n}(F)$ for F a non-archimedean local field, and state results relative to the classification of representations of quasi-split unitary group in four variables over local and global fields with nontrivial symplectic periods using methods of theta correspondence.

If time permits, we will propose a conjectural answer for the classification of all representations of a quasi-split unitary group with symplectic period.

Distinguishing Cusp forms with Real Fourier Coefficients

Sanoli Gun
IMSc, Chennai, India

One of the important themes in the theory of modular forms is to distinguish them via arithmetic properties of their Fourier coefficients. There are several ways to do it. In this talk, we will discuss one such method to distinguish cusp forms with real Fourier coefficients.

Bernstein Center of Supercuspidal Blocks

Manish Mishra
IISER, Pune, India

Let G be a connected reductive group defined over a non-archimedean local field k. The center of the category of smooth representations of $G(k)$ is called the Bernstein center. I will review some basic results in the theory of Bernstein center. At the end, I will state my result about the Bernstein center of supercuspidal blocks.

Integral Representation and Critical L-values for Holomorphic Forms on $\mathrm{GSp}(2n) \times \mathrm{GL}(1)$

Ameya Pitale
University of Oklahoma, Norman, USA

In this talk, we will report on recent joint work with Abhishek Saha and Ralf Schmidt on integral representation of the standard L-function for holomorphic vector-valued Siegel modular forms of arbitrary genus and with respect to arbitrary congruence subgroup. A lot of work has been done on this topic by Andrianov, Harris, Sturm, Garrett, Shimura, Piatetski-Shapiro, Rallis and many others. To obtain the most general result, we adopt the adelic approach and obtain the pullback of an Eisenstein series on $\mathrm{GSp}(4n)$ to $\mathrm{GSp}(2n) \times \mathrm{GSp}(2n)$. The innovation is the choice of vectors in the ramified and the archimedean cases allowing us to get explicit formulas. The potential applications are arithmeticity of special values of L-functions as algebraic numbers (normalized by suitable periods), and one can further ask the prime factorization of those algebraic numbers. We will report on the arithmeticity results for the genus 2 case, which involves a deeper understanding of the structure of nearly holomorphic modular forms.

Rational Points on Complex Surfaces of Hyperbolic Type

Dinakar Ramakrishnan
California Institute of technology, Pasadena, CA, USA

A basic problem in number theory, going back to Diophantos, is to understand the rational solutions of systems of polynomial equations with integer coefficients. This is recast usually in terms of rational points on the algebraic variety V defined by the polynomial system. An intriguing principle is that the geometry of the complex variety $V(C)$ has a strong bearing on the set $V(Q)$ of rational points. A conjecture of Lang predicts a strong finiteness result when $V(C)$ is hyperbolic, which we will explicate when $V(C)$ is uniformized by the unit complex ball, representing some joint work with M. Dimitrov.

Periods, Modular Forms and Transcendence

Purshottam Rath
Chennai Mathematical Institute, Chennai, India

The ring of Periods, introduced by Kontsevich and Zagier is a mysterious subring of the field of Complex numbers containing all the algebraic numbers. In this talk, we shall illustrate periods originating from the realms of Modular forms and discuss about their possible transcendental nature.

Whittaker Vectors via Hecke Algebras

Speaker: Gordan Savin
University of Utah, Salt Lake City, USA

Let G be a split reductive group over a p-adic field F. Let B be a Borel subgroup and U the maximal unipotent subgroup of B. Let be a Whittaker character of U. Let I be an Iwahori subgroup of G. We describe the Iwahori-Hecke algebra action on the Gelfand-Graev representation $(ind_U^G \psi)^I$ by an explicit projective module. As a consequence, for $G = GL(n, F)$, we define and describe Bernstein-Zelevinsky derivatives of representations generated by I-fixed vectors in terms of the corresponding Iwahori-Hecke algebra modules. Furthermore, using Lusztig's reductions, we show that the Bernstein-Zelevinsky derivatives can be determined using graded Hecke algebras. We give two applications of our study. Firstly, we compute the Bernstein-Zelevinsky derivatives of generalized Speh modules, which recovers a result of Lapid-Ḿinguez and Tadić. Secondly, we give a realization of the Iwahori-Hecke algebra action on some generic representations of $GL(n+1, F)$, restricted to $GL(n, F)$, which is further used to verify a conjecture on an Ext-branching problem of D. Prasad for a large class of examples. This is a joint work with Kei-Yuen Chan.

Symmetries in the Distribution of Prime Polynomials

Dinesh Thakur
University of Rochester, Rochester, New York, USA

The primes or prime polynomials (over finite fields) are supposed to be distributed 'irregularly' , despite nice asymptotic or average behavior. We explain some conjectures and results on exact symmetries in prime distribution leading to vanishing or rationality of several types of infinite sums over prime polynomials, and regularity of some finite sums.

Symposium on 'Operations Research and Mathematical Programming'

Organisers: *M. Rammohan Rao* (IIM Bangalore, India)
and *Gerard Cornuejols* (Carnegie Mellon University, USA)

The Optimal Communication Spanning Tree Problem : An Exact Solution Approach via Disaggregate Flow Formulation and New Valid Inequalities

Yogesh K Agarwal
Indian Institute of Management, Lucknow, India

Given a graph $G = (V, E)$, a set of traffic demands among the nodes, and per unit flow cost for the edges of G, we consider the problem of designing a tree so as to minimize the flow costs of all demands if each demand is routed along the unique path in this tree. Each edge is assumed to have unlimited capacity, and there are no fixed costs of installing the edges. We consider the traditional flow formulation in which the traffic between each origin-destination pair is treated as a separate commodity. Several new classes of valid inequalities are developed for this formulation. On relatively small problems of up to 10 nodes, addition of these inequalities leads to integer solutions in a large majority of cases. In the remaining cases, the LP solution is within 1% of optimal solution. For larger problems, these inequalities substantially improve the root node bound, and reduce the CPU time as well as the branch and bound tree size for solving the problem. Optimal solutions are reported for problems with 30 nodes, 60 edges, and fully dense traffic matrices. Some polyhedral issues relating to the strength of these inequalities are also discussed.(A joint work with Prahalad Venkateshan, I.I.M. Ahmedabad)

Embedding Graphs Over Elliptopes: An Inexact Prox Function Based Approach

Chiranjib Bhattacharyya
Computer Science andAutomation, Indian Institute of Science, Bangalore, India

Learning labels on a graph, an important problem in Machine Learning, can be accomplished by embedding the graph over an Elliptope. The optimal embedding can be computed by minimising a convex non-smooth function over an elliptope. Such problems are often posed as instances of SemiDefinite programming(SDP). Interior point methods for SDPs often have a computational complexity of $O(n^6)$ and are not suitable for large scale applications. We describe an inexact prox function based approach which in T iterations reach a solution which is atmost $O(1/sqrtT)$ more than the objective function and each iteration is $O(n^3)$. Our algorithm easily scales to graphs with tens of thousands of vertices while SDP based approaches cannot go beyond a few hundred vertices.

Solving the Two-Facility Network Design Problem with 3-Partition Facets

Faiz Hamid
Indian Institute of Technology, Kanpur, India

The research studies the problem of designing telecommunication networks using transmission facilities of two different capacities. The point-to-point communication demands are met by installing a mix of facilities of both capacities on the edges to minimize total cost. We consider 3-partitions of the original graph which results in smaller 3-node subproblems. The extreme points of this subproblem polyhedron are characterized using a set of propositions. A new approach for computing the facets of the 3-node subproblem is introduced based on polarity theory. The facets of the subproblem are then translated back to those of the original problem using a generalized version of a previously known theorem. The approach has been tested on several randomly generated and real life networks. The computational results show that the new family of facets significantly strengthen the linear programming formulation and reduce the integrality gap. Also, there is a substantial reduction in the size of the branch-and-bound tree if these facets are used. Problems as large as 37 nodes and 57 edges have been solved to optimality within a few minutes of computer time.

Automatic Reformulation of MINLPs: Separability and Perspectives

Ashutosh Mahajan
Indian Institute of Technology, Mumbai, India

A convex MINLP is an optimization problem in which some of its variables are required to be integer valued and all nonlinear functions in the objective and constraints are convex. Like its linear counterpart, the MILP, MINLP is an NP-Hard problem, and can be solved using branch-and-cut algorithms. The performance of these algorithms depends on how well one detects and exploits particular structures in the given instance. We study two such structures: separability in the nonlinear functions and perspective reformulations. We have implemented algorithms to identify these structures automatically in a MINLP instance and also to reformulate the instance so that it becomes more tractable to solve. We will describe

these methods and their limitations. Our experiments show that exploiting these structures can significantly reduce the solution time for benchmark instances. This work was jointly done with Meenarli Sharma at IIT Mumbai, India.

Formulations of the Traveling Salesman Problem

Usha Mohan
Indian Institute of Technology, Madras, India

The asymmetric traveling salesman problem is defined on a directed graph $G = (V, A)$, where $V = \{1, 2, \ldots, n\}$ is the set of vertices and $A = \{(i, j)|i, j \in V\}$ is the set of edges with a cost, c_{ij}, defined on A. The TSP problem is to determine an optimal tour(Hamiltonian circuit) over G.

As is the case with most combinatorial optimization problems, exact algorithms for solving the TSP combine polyhedral results with enumeration, where the efficiency of enumeration depends on the strength of the LP relaxation of the given formulation.

In this talk, we introduce the Traveling Salesman Problem(TSP). We present a review and classification of the formulations of the TSP. In particular, we discuss the LP relaxations of the formulations and do a comparative analysis of the same.

A New Disaggregated Formulation of the Generalized Assignment Problem and its Associated Valid Inequalities

Ishwar Murthy
IIM, Bangalore, India

We present a new disaggregated formulation of the Generalized Assignment Problem (GAP), consisting of $O(mn^2)$ variables and constraints, where m denotes the number of agents and n the number of jobs. In contrast, the traditional formulation consists of $O(mn)$ variables and constraints. The disaggregated formulation is stronger than the traditional formulation; the linear programming relaxation of the disaggregated formulation provides tighter lower bounds. Furthermore, this new formulation provides additional opportunities for generalizations of the well-known Cover and $(1, k)$-Configuration inequalities that are not present in the traditional formulation. They are facet defining for the knapsack polytopes. We also introduce two classes of inequalities involving multiple agents that are specific to this formulation. Both inequalities are defined on an appropriate sub-graph of the bipartite graph that represents GAP. One class of inequalities is called the Bar-and-Handle Inequalities. We show them have to be facets of the polytope defined by its associated sub-graph. Finally, we introduce another important class of inequalities called Cardinality Matching Inequalities. Given the un-capacitated version of GAP in which each agent can process all the jobs, we show that a class of Cardinality Matching inequalities are indeed facets of the polytope

defined by the associated bipartite graph.(A joint work with Sam Ransbotham Carroll School of Management,Boston College, Chestnut Hill, MA 02467, USA)

Local Polyhedrality of Some Integer Hulls

Vishnu Narayanan
IIT, Bombay, India

This talk concerns the structure of integer points of convex sets. In general, the convex hull of integer points (the integer hull) can have a messy structure. However, we show that the integer hull of a strictly convex set is locally polyhedral, i.e., its intersection with every polytope is a polytope. We show that this result also holds for all convex sets not containing integer points in their boundary. This is joint work with Umakanta Pattanayak.

Optimising The Logistics Cost in a Cement Factory

Ravichandran
Indian Institute of Management Ahmedabad, India

This paper documents the experience of optimizing the logistics operations cost in a cement plant. The logistics cost accounts for 20% of the turnover of the factory. We develop a model to reduce the cost of logistics operations and address a range of issues related to serving remote location markets, mutimodal transportation, quantity restriction in obtaining concession rail tariff, taxation issues, and demand variability. The model resulted in a savings of 10% of the logistics budget. The model and its benefit was verified with the real data of the previous year .A decision support system was developed to institutionalize the optimization efforts. The paper concludes the experience in implementing the model.

Symposium on 'Partial Differential Equations'

Organisers: *Mythily Ramaswamy* (Tata Institute of Fundamental Research-CAM, Bangalore, India)
and *Rakesh* (University of Delaware, Newark, USA)

Finite Element Methods for Fourth Order Elliptic Variational Inequalities

Susanne Brenner
Louisiana State University, Baton Rouge, USA

Fourth order elliptic variational inequalities appear in obstacle problems for Kirchhoff plates and optimization problems constrained by second order elliptic partial differential equations. The numerical analysis of these variational inequalities is more challenging than the analysis in the second order case because the complementarity forms of fourth order variational inequalities only exist in a weak sense. In this talk we will present a unified framework for the a priori analysis of finite element methods for fourth order elliptic variational inequalities that are applicable to C1 finite element methods, classical nonconforming finite element methods, and discontinuous Galerkin methods.

Finite Element Approximation of Obstacle Problem

Tirupathi Gudi
IISc, Bangalore, India

We present the finite element discretization of the elliptic obstacle problem and discuss the convergence analysis. Generally, the obstacle problem exhibits free boundary along which the regularity of the solution is affected. The convergence analysis needs to be derived under the realistic regularity. In the discussion, linear and quadratic finite element methods will be considered.
Further, we discuss the a posteriori error control of those discretizations and design an adaptive mesh refinement algorithm for efficient computations. We illustrate the theoretical results by some numerical experiments.

Uniqueness Results for Calderon-Type Inverse Problems

Venky Krishnan
Tata Institute of Fundamental Research-CAM, Bangalore, India

We consider certain Calderon type inverse problems and show the unique recovery of lower order coefficients of the PDE from partial boundary Dirichlet-to-Neumann data.

A Kinetic Theory for 2D Grain Boundary Coarsening

Govind Menon
Brown University, Providence, USA

An important recent development in applied mathematics is the growing interest in 'stochastic topology'. Natural examples of stochastic topologies are provided by cellular networks such as a froth of soap bubbles, consisting of a large number of bubbles with different sizes and connectivity.

This talk describes the interplay between kinetic theory, probability theory and topology in a basic example– isotropic 2D grain boundary networks. A fundamental aspect of these

networks is the Mullins-von Neumann $n-6$ rule: the rate of change of the area of a (topological) n-gon is proportional to $n-6$. As a consequence, cells with fewer than 6 sides vanish in finite time, and the network coarsens. Numerical and physical experiments have revealed a form of statistical self-similarity in the long time dynamics that is not understood.

We propose a kinetic description for the evolution of such networks. The ingredients in our model are an elementary N particle system that mimics essential features of the Mullins-von Neumann rule, and a hydrodynamic limit theorem for population densities when $N \to \infty$. This theorem is broad enough to include all kinetic equations proposed by physicists in the 1980s and 1990s. In fact, many of these equations conflict with one another, and our model allows us to examine the foundations of each of the kinetic theories and to compare them with computational data. It also allows us to begin to attempt to connect kinetic theory with what are still preliminary attempts to understand the stochatic topology of cellular networks.

This is joint work with Joe Klobusicky (Rensselaer Polytechnic Institute) and Bob Pego (Carnegie Mellon University).

Homogenization of an Optimal Control Problem in an Oscillating Domain

A. K. Nandakumaran
Indian Institute of Science, Bangalore, India

The theory of homogenization has applications in many branches of science and engineering which includes composite materials, porous media, rapidly oscillating (rugous boundary) domains and so on. In this talk, we introduce certain domains whose boundaries are rapidly oscillating. Then, we consider an optimal control problem in a sample domain with highly oscillating boundary. The controls will be acting on the oscillating boundary making the problem more interesting and challenging. We characterize the optimal control via the so called unfolding operator which was introduced to study homogenization. This characterization is completely new and it is a novel approach. We, then do the limiting analysis of the optimal control problem to obtain the limit optimal control problem. In the process, we also briefly introduce two scale convergence and unfolding method which are, indeed introduced to study homogenization, but it is interesting in its own way.

The Inverse Back-Scattering Problem

Rakesh
University of Delaware, Newark, USA

An acoustic medium is probed by plane waves from all directions and the medium response is measured back in the same directions. The goal is the recovery of the acoustic properties of the medium from this back-scattered data. Specifically, suppose $q(x)$ is a compactly supported smooth function on R^3, representing the acoustic property of a medium.

For each unit direction ω in R^3, let $u(x,t;\omega)$ be the solution of the initial value problem

$$u_{tt} - \Delta_x u + q(x)u = 0, \qquad (x,t) \in R^3 \times R$$
$$u(x,t;\omega) = \delta(t - x\cdot\omega), \qquad x \in R^3,\ t << 0.$$

The back-scattering data, in the direction ω, with delay s, is

$$\beta(s,\omega) = \lim_{r\to\infty} u(r\omega, r - s\,\omega), \qquad s \in R,\ \omega \in R^3,\ |\omega| = 1.$$

The inverse back-scattering problem is the study of the non-linear map

$$: q(\cdot) \to \beta(\cdot,\cdot),$$

particularly the injectivity and the inversion of . We survey the results for this long-standing unsolved problem, based on work done with Gunther Uhlmann.

Moser-Trudinger and Adams Inequalities

Sandeep
Tata Institute of Fundamental Research-CAM, Bangalore, India

Embeddings of Sobolev spaces play an important role in the analysis of partial differential equations. We will discuss some of these sharp embeddings known as Moser-Trudinger and Adams Inequalities and present some of the recent results obtained.

On Two Dimensional Gravity Water Waves with Angled Crests

Sijue Wu
University of Michigan, Ann Arbor, USA

In this talk, I will survey the recent understandings on the motion of water waves obtained via rigorous mathematical tools, this includes the evolution of smooth initial data and some typical singular behaviors. In particular, I will present our recent results on gravity water waves with angled crests.

Symposium on 'Physical Mathematics'

Organisers: *Kishore Marathe* (Brooklyn College, City University of New York, USA) and *Louis Kauffman*, (University of Illinois, Chicago, USA)

Unitary Representations of Atrin Braid Groups

John Bryden
Fahd University, Saudi Arabia

Vulgar Understanding the representation theory of the Artin braid groups would lead to progress in a number of important areas of contemporary mathematics, including topological quantum field theory and quantum computation. Every infinite discrete group has an associated topological spectrum which can be utilized in some cases to find its irreducible representations. In particular this method can be applied to the Artin braid groups, which is the subject of this talk.

The Quillen Determinant Bundle and Geometric Quantization of Various Moduli Spaces

Rukmini Dey
ICTS, Bangalore, India

We will give a brief introduction to geometric quantization and Quillen's determinant line bundle. Then we will describe the quantization of various moduli spaces arising from physics using the Quillen construction. Examples include the Hitchin system and the vortex moduli space. We will also talk about a general theorem which essentially says that the quantum bundle (or a tensor power of the same) can be realised as a Quillen determinant bundle.

Braiding of Majorana Fermions

Louis Kauffman
University of Illinois, Chicago, USA

Majorana fermions are Fermionic particles that are their own anti-particles. Mathematically, a standard fermion such as an electron can be seen as a 0$\breve{8}$232 composite of two Majorana fermions. At the level of operators in quantum field theory this is seen by writing $F = a+ib$ where F is the fermion annihilation operator and a and b are elements of a Clifford algebra where $a^2 = b^2 = 1$ and $ab = -ba$. Then $F* = a - ib$ and we have $F^2 = F*^2 = 0$ and $FF* + F*F$ is a scalar. This talk will discuss the braiding structure of Majorana fermions, possible applications to topological quantum computing and ways to understand the mathematical meaning of the Fermion operators. The corresponding plenary talk will go into more detail about models such as the Fibonacci model for topological quantum computing.

How to Build a Device that Cannot Be Built?

Sam Lomonaco
University of Maryland, Baltimore County, USA

In this paper, we show how the GHZ paradox can be used to design a computing device that cannot be physically implemented within the context of classical physics, but nonetheless can be within quantum physics, i.e., in a quantum physics laboratory. This example gives an illustration of the many subtleties involved in the quantum control of distributed quantum systems. We also show how the second elementary symmetric Boolean function can be interpreted as a quantification of the nonlocality and indeterminism involved in the GHZ paradox.

What is Physical Mathematics?

Kishore Marathe
City University of New York, New York, USA

Physical mathematics is a new and very active area of research at the interface of physics and mathematics. However, its roots go back to antiquity. We will discuss the ancient origins of this subject and highlight some important achievements in this area leading up to current developments. They have given us surprising new results and new perspectives on old results in mathematics starting with results from experimental and theoretical physics.

Weaving Knots and Their Invariants

Rama Mishra
IISER, Pune, India

A Weaving knot $W(p, q)$ of type (p, q) is an alternating knot with the same projection as torus knot of type (p, q). Weaving knots originally attracted interest, because it was conjectured that their complements would have the largest hyperbolic volume for a fixed crossing number. Champanerkar, Kofman, and Purcell studied the asymptotic behaviour of the volume of the complement of $W(p, q)$ as p and q approach infinity. Their study raised the question of examining the asymptotic behavior of other invariants of weaving knots. In this talk we explore the invariants like signature, Jones polynomial and the Khovanov Homology of Weaving knots and start a study of the asymptotic behavior of Khovanov homology of weaving knots $W(3, n)$ as n tends to infinity.

Generalized Seiberg-Witten Equations and HyperKähler Geometry

Varun Thakre
Harish Chandra Research Institute, Allahabad, India

In this talk, I shall discuss a gauged, non-linear sigma-model in 4-dimensions introduced by Taubes and Pidstrygach. The central element of this model is the construction of a

non-linear Dirac operator, obtained by replacing the spinor representation with hyperKähler manifolds with certain symmetries. I shall highlight the role of harmonic and parallel generalized spinors in defining Kähler and Symplectic structures on the base manifold, for some interesting target hyperKähler manifolds. Also, I will talk about a dimensional reduction of the generalized Seiberg-Witten equations to 2-dimensions and discuss some nice properties of its moduli space of solutions.

Symposium on 'Probability Theory and Stochastic Processes'

Organisers: *Arup Bose* (Indian Statistical Institute, Kolkata, India) and *Richard Davis* (Columbia University, USA)

Invertibility of Sparse Random Matrices

Anirban Basak
Weizmann Institute, Israel

We consider a class of sparse random matrices of the form $A_n = (\xi_{i,j}\delta_{i,j})_{i,j=1}^n$, where $\{\xi_{i,j}\}$ are i.i.d. centered random variables, and $\{\delta_{i,j}\}$ are i.i.d. Bernoulli random variables taking value 1 with probability p_n, and prove a quantitative estimate on the smallest singular value for $p_n = \Omega(\frac{\log n}{n})$, under a suitable assumption on the spectral norm of the matrices. This establishes the invertibility of a large class of sparse matrices. We also find quantitative estimates on the smallest singular value of the adjacency matrix of a directed Erdős-Réyni graph whenever its edge connectivity probability is above the critical threshold $\Omega(\frac{\log n}{n})$.

This is joint work with Mark Rudelson.

High Dimensional Linear Time Series and Free Probability

Arup Bose
Indian Statistical Institute, Kolkata, India

Suppose we have n observations on a linear time series of dimension p, where both n and p are large such that $p/n \to y \in [0, \infty)$. One way to study the sample autocovariance matrices is to consider the spectral distribution of (symmetric) polynomials of these matrices. We develop the large sample behaviour of these spectral distributions. The results are significantly different for the two cases: $y = 0$ and $y \neq 0$. The limit distributions often cannot be computed explicitly. But they can be described via non-commutative free variables. Nevertheless, these results can be used in statistical inference problems such as estimation of high dimensional parameter matrices, determination of the order of the process and testing if the process is a white noise.

Limit Laws and Statistical Mechanics

Federico Camia
New York University, Abu Dhabi, UAE

In the last twenty years there has been tremendous progress in the mathematical understanding of phase transitions in lattice models of statistical mechanics in two dimensions such as percolation and the Ising model. Much of that progress is related to the study of scaling limits, obtained by sending the lattice spacing to zero. In this talk I will give a brief introduction to scaling limits in two-dimensional statistical mechanics and discuss some recent results in the mathematical theory of phase transitions.

Asymptotic Behaviour of Gaussian Minima

Arijit Chakrabarty
Indian Statistical Institute, Kolkata, India

In this joint work with Gennady Samorodnitsky, we investigate what happens when an entire sample path of a smooth Gaussian process on a compact interval lies above a high level. Specifically, we determine the precise asymptotic probability of such an event, the extent to which the high level is exceeded, the conditional shape of the process above the high level, and the location of the minimum of the process given that the sample path is above a high level.

Random Matrix Ensembles with Split Limiting Behavior

Steven J. Miller
Williams College, Massachusetts, USA

Random matrix theory has successfully modeled a variety of systems, from energy levels of heavy nuclei to zeros of the Riemann zeta function. One of the central results is Wigner's semi-circle law: the distribution of normalized eigenvalues for ensembles of real symmetric matrices converge to the semi-circle density (in some sense) as the matrix size tends to infinity. We introduce a new family of $N \times N$ random real symmetric matrix ensembles, the k-checkerboard matrices, whose limiting spectral measure has two components. All but k eigenvalues are in the bulk, and their behavior, appropriately normalized, converges to the semi-circle as $N \to \infty$; the remaining k are tightly constrained near N/k and their distribution converges to the $k \times k$ hollow GOE ensemble (this is the density arising by modifying the GOE ensemble by forcing all entries on the main diagonal to be zero). Similar results hold for complex and quaternionic analogues. We are able to isolate each regime separately through appropriate choices of weight functions for the eigenvalues and then an analysis of the resulting combinatorics. This is joint work with Paula Burkhardt, Peter Cohen, Jonathan Dewitt, Max Hlavacek, Carsten Sprunger, Yen Nhi Truong Vu, Roger Van Peski, and Kevin Yang.

Convergence of Drainage Networks to Brownian Web and Some Applications

Anish Sarkar
Indian Statistical Institute, New Delhi, India

We consider various models of directed random trees, originating from various fields such such drainage network models, percolation models etc.. Most of these models, under a suitable scaling, converge to the Brownian web. The Brownian web can be loosely described as the a coalescing system of Brownian paths, with paths starting from every point of the two dimensional plane. This convergence can further be exploited to derive results about the models and we will provide couple of examples.

Cylindric and Radial Brownian Webs

TRAN Viet Chi
University of Lille, France

The Brownian web on the plane (BW), introduced by Arratia (79) Tóth and Werner (98) and Fontes et al. (04), is formed by a family of coalescing Brownian trajectories $(W_{x,t}, (x,t) \in R^2)$, starting at each point (x,t) of R^2. This object can be constructed as continuous limit of various discrete models of directed forests of coalescing random walks and navigation schemes, which has been much studied in the literature. Recently, radial (2D) counterparts of these discrete directed forests have been considered and naturally, attemps have been carried for obtaining invariance principles for these objects and define a "radial BW". Nevertheless, the rescaling needed in the BW case is somehow incompatible with a "nice Brownian limit"in the radial case and the limits are considered only locally. We propose in this talk the creation of the cylindric Brownian web (CBW) that allows to involve the angular characteristic of the radial problems, while keeping a geometry close to the plane. The properties of the CBW and the differences with the BW are considered.
For limit theorems, we show that many convergence results on the plane leading to the BW can be turned into convergence results on the cylinder with the CBW. A particular focus is given to discrete models that can be defined naturally on $R \times R$ and on R/Z: for example, directed forests constructed from homogeneous Poisson point processes (say with intensity 1) can be defined on both these spaces with the same local definitions.
Next, we obtain "radial Brownian webs"by projecting the cylinder on the plane R^2: for this, we send slices $R/Z \times \{h\}$, on circles centered at the origin 0 and of radius $r(h)$, given a strictly increasing function $r(.)$. Each of these projections maps families of coalescing paths on the cylinder to coalescing families of radial paths. Proceeding like this, discrete directed forests on the plane are mapped to discrete forests on the cylinder and then to radial planar forests. Similarly, discrete radial forests can be mapped on the cylinder, on which convergence results to the CBW can be shown.

This is a joint work with David Coupier (Univ. Lille 1) and Jean-François Marckert (Univ. Bordeaux 1).

Symposium on 'Quality Control and Statistical Reliability'

Organisers: *S. K. Upadhyay* (BHU, Varanasi, India), *Nirpeksh Kumar* (BHU, Varanasi, India)
and *J.V. Deshpande* (Chennai Mathematical Institute, Chennai, India)

Statistical Process Control Charts: Current Status and Future Directions

S. Chakraborti
University of Alabama, Tuscaloosa, USA

Statistical process control and monitoring (SPCM) isa highly active area of research where statistical methods are devised and applied to solve real world problems. This area of work, which grew out of the manufacturing industry in the 50's and the 60's,has seen a tremendous growth in the number of research publications in the last few years, and remains relevant in traditional as well as big data situations. In this general talk, an overview of some parts of the ever growing landscape of the current state of SPC research on control charts will be given. The focus will be on univariate charts. The topicswill include both parametric and nonparametric control charts, the nonparametric charts are useful in practice since minimal assumptions are required. Some current research topics will be described along with possibilities for future work.

Control Charts Based On Spatial Autoregressive Moving Average Models

Anoop Chaturvedi
University of Allahabad, Allahabad, India

For modeling spatial data on grid involving autocorrelation structure, Spatial Autoregressive (SAR) and Spatial ARMA (SARMA) processes have been explored. The control charts for the observations taken over a grid on a two-dimensional surface have been considered. The Spatial AR process has been applied to model the autocorrelation structure of the observations and control charts for mean and standard have been developed. The Max-Exponentially Weighted Moving Average (Max-EWMA) Charts for the 2-D observation following SAR process have been proposed. An application to monitor the road pavement data has been discussed to illustrate the results. The exact and large sample approximations for the moments and probability distribution of process capability index have been investigated.

Modelling Repairable Systems with a Burn-in Period

Isha Dewan
Indian Statistical Institute, New Delhi, India

We consider a complex repairable systems with a burn in period. The system is subject to corrective maintenances and planned preventive maintenances. We use competing risks to model the maintenance process. An algorithm is proposed to estimate the parameters of the model under missing causes of failure. (A joint work with Yann Dijoux)

Discrete Time Software Reliability Modeling with Periodic Debugging Schedule

Anup Dewanji
Indian Statistical Institute, Kolkata, India

In many situations, multiple copies of a software are tested in parallel with different test cases as input, and the detected errors from a particular round of testing are debugged together. In this work, we discuss a discrete time model of software reliability for such a scenario of periodic debugging. We propose likelihood based inference of the model parameters, including the initial number of errors, under the assumption that all errors are equally likely to be detected. The proposed method is used to estimate the reliability of the software. We establish asymptotic normality of the estimated model parameters. The performance of the proposed method is evaluated through a simulation study and its use is illustrated through the analysis of a dataset obtained from testing of a real-time flight control software. We also consider a more general model, in which different errors have different probabilities of detection.

Improved Phase II Shewhart-Type Exponential Chart when Phase I Sample Size is Small

Nirpeksh Kumar
Banaras Hindu University, Varanasi, India

In this paper, we consider Shewhart type exponential chart for monitoring times between events (TBE) which is sometimes called the t-chart. When the rate parameter is not known, it is customary that the 'plug-in' control charts are constructed by replacing the parameter by its suitable estimator. However, it is well established that the conditional as well unconditional performance of the 'plug-in control charts are widely affected by the choice of the estimator, especially, when the Phase I sample size is small. We took into account the various choices of the estimator other than the UMVUE and it is shown that the chart performance can be improved to large extent by considering the biased estimators and hence, the bias-correction is not recommended in contrary to the earlier works. On the other hand,

due to consideration of TBEs, the availability of sufficient amount of Phase I observations in not feasible to reduce the 'so-called' practitioner-to-practitioner variability. Hence, we also design the t-chart to make optimal in respect of various performance metrics for given Phase I sample size. An example is also given to illustrate the results.

Estimation of Component Reliability Measures using Hybrid Censored Masked System Lifetime Data from Maxwell Distribution

Sanjeev Kumar
Banaras Hindu University, Varanasi, India

In life testing experiments, conducted for multi-component series systems, the estimation of component reliability measures using system lifetime data is often considered. Since a series system fails as soon as any one of its component fails, the observed data may consists of lifetimes of failed systems as well as an indicator denoting the component which causes the system failure. The analysis of such data can be performed using competing risk model in order to asses various components characteristics. Several authors have discussed the problem of estimation of reliability measures of individual components using system lifetime data under competing risk model when lifetimes and corresponding cause of failure for all the failed systems are available. But, sometimes, the component which causes the system failure cannot be identified for some of the systems put on the test. In such cases we have incomplete data in respect of cause of failure which are also called 'masked' data in literature. In the present talk, we discuss Bayesian estimation of components reliabilities, mean lives and hazard rates using hybrid censored masked series system lifetime data when the lifetimes of the components follow Maxwell distribution. We consider the cases of independent as well as dependent maskings and study the performance of various estimators. We present numerical illustrations using simulation study.

b-value Characterization and its Application in Earthquake Statistics

Santanu Manna
Indian Institute of Technology, Indore, India

b-value is the slope on the log(N M) regression line of Gutenberg and Richter (19420 frequency-magnitude distribution relation: $\log_{10} N(M) = a - bM$. In which N is the number of earthquakes with magnitude greater than or equal to M occurring in a given time period. It is known to us that the occurrences of earthquake are uncertain. So computing the exact magnitude of completeness is the important thing to follow the calculation of b-value from the thousands of real earthquake seismic DATA. Statistical methods (MLE and EMR) have been used to compute the exact magnitude of completeness from the set of DATA. For seismic DATA set purpose we have used the global seismic international networks IRIS, USGS, ISC. After computing b-value we followed to investigate the earthquake statistics using various

earthquake source parameters. Finally draw a conclusion regarding the prediction of future earthquakes.

Study of Systems under Proportional Odds Model

Asok K. Nanda
IISER, Kolkata, India

The reliability properties under proportional hazards model have been extensively studied in the literature. However, not much work have been done on proportinal odds model. In this talk we shall investigate various stochastic ordering results under this model for series and parallel systems having heterogeneous component lifetimes. We also study relative ageing orderings for two systems.

A large portion of the talk is based on a joint work with Dr. Pradip Kundu, IISER Kolkata and Dr. Nilkamal Hazra, University of the Free State, South Africa.

Bayes Analysis of Certain Low Dimensional Competing Risk Models

S. K. Upadhyay
Banaras Hindu University, Varanasi, India

The present talk focuses on several low dimensional competing risk models obtained by considering combinations of increasing, decreasing and constant hazard rate lifetime families where the causes of failures may often be latent. The appropriate competing risk models are proposed and analyzed in a Bayesian framework. Classical maximum likelihood estimation is also attempted as an aid to our Bayesian computation. The simplicity of sample based approaches clearly demonstrates the scope of Bayesian paradigm in such modelling scenarios. Appropriate numerical illustrations are provided throughout.

Symposium on "Symplectic Topology"

Organisers: *Dishant Pancholi* (Chennai Mathematical Institute, Chennai, India) and *Y. Eliashberg* (Stanford University, Palo Alto, California, USA)

Legendrian Front for Affine Varieties II: Applications

Roger Casals
Massachusetts Institute of Technology, Boston, USA

In this series of two talks we discuss Weinstein structures endowed with Lefschetz fibrations in terms of Legendrian front projections. This second talk is focused on applications of this Lefschetz–Front dictionary. These include the description of Stein handlebodies of affine algebraic varieties, the detection of flexible and subflexible Weinstein structures and the existence of exact Lagrangian submanifolds. In particular, we will show that the Koras–Russell cubic is Stein deformation equivalent to the complex affine 3–space and compute the mirror functor for the complement of a conic. This is joint work with Emmy Murphy.

Floer Theory and Critical Values of Complex-Valued Functions

Sheel Ganatra
University of Southern California, USA

Given a (tame at infinity) holomorphic function on a complex variety with isolated (but possibly degenerate) singularities, what is the minimum number of critical values of any tame complex deformation (with isolated, but also possibly degenerate singularities)? We prove there is a symplectic Floer/Fukaya-theoretic lower bound for the answer, as conjectured by Seidel and previously studied in the non-degenerate singularity case. Using this bound, one can find examples of varieties and holomorphic functions having arbitrarily large numbers of critical values that cannot be holomorphically deformed away, even though they smoothly can.

Symplectic Embeddings in High Dimension

Richard Hind
University of Notre Dame, Indiana, USA

The study of symplectic embeddings started with Gromov's famous non- squeezing theorem describing when there exists an embedding from a ball into a cylinder. The question of when symplectic embeddings exist between general ellipsoids and polydisks remains largely open, and answers to special cases in dimension 4 have been surprisingly intricate. I will describe joint work with Cristofaro-Gardiner, McDu and Opshtein, focussed on extending known results about embeddings of ellipsoids, polydisks and Lagrangian tori to higher dimension.

Legendrian Fronts for Affine Varieties I: Construction

Emmy Murphy
Radcliffe Institute for Advanced Study, USA

In this series of two talks we describe Weinstein structures endowed with Lefschetz fibrations in terms of Legendrian fronts. This first talk is focused on the construction and proof

of this Lefschetz–Front dictionary, translating Weinstein Lefschetz fibrations to Legendrian links; the main focus is on A_k–biLefschetz fibrations. In particular, the front presentation of a Dehn twist and Legendrian handle slides will be discussed, along with the basic features of higher–dimensional Legendrian calculus. This is joint work with Roger Casals.

Quantitative Transversality in Symplectic Geometry

John Pardon
Stanford University, Palo Alto, Califorina, USA

I will survey some applications of Donaldson's technique of quantita- tive transversality of "approximately holomorphic" functions in symplec- tic geometry. I will explain the basic terms and present the main ideas of the technique. Donaldson used it to show that the Poincare dual of any sufficiently large multiple of an integral symplectic form is represented by a symplectic submanifold. Another application is joint work with E. Giroux in which we prove the existence of Lefschetz fibrations on certain symplectic manifolds.