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Keynote Talk

Multiple orthogonal polynomials and applications in quadrature and wavelets

KT

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Multiple orthogonal polynomials are polynomials in one variable that satisfy orthogonality conditions with respect to several measures. I will briefly give some general properties of these polynomials (recurrence relation, zeros etc.). These polynomials have recently appeared in many applications, such as number theory, random matrices, non-intersecting random paths, integrable systems etc. I will speak about two applications. The first is an extension of the Gauss quadrature formula for integrating a function, to simultaneous quadrature where one wants to integrate one function with respect to several measures. The second application is the construction of multiwavelets by means of polynomials, which uses Legendre polynomials and multiple orthogonal polynomials known as Legendre-Angelesco polynomials.

Plenary Talks

Recent Trends on the Bohr inequality

PT-01

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The classical Bohr's theorem deals with determining the largest radius r, $0 < r < 1$, such that $\sum_{n=0}^{\infty} |a_n| r^n \leq 1$ holds whenever $\sum_{n=0}^{\infty} a_n z^n$ converges and bounded by 1 in the unit disk $\mathbb{D}$ of the complex plane. The exact value of this largest radius, known as the *Bohr radius*, has been established to be $1/3$. We shall discuss some recent issues and extension of this idea in various field.

In particular, Balasubramanian [1] *et al.* extended the Bohr inequality to the setting of Dirichlet series and there by the authors bring the Bohr phenomenon back to its origins since Bohr radius for power series on the disk originated from studying problems on absolute convergence in the theory of Dirichlet series.

For $1 \leq p < \infty$, let D^p be the space of ordinary Dirichlet series consisting of $f(s) = \sum_{n=1}^{\infty} a_n n^{-s}$ in $\mathbb{H} = \{s = \sigma + it : \sigma > 0\}$ corresponding to the Hardy space of order p. The space D^p is the completion of the space of Dirichlet polynomials $P(s) = \sum_{n=1}^{N} a_n n^{-s}$ in the norm

$$\|P\| = \left(\lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} |P(it)|^p \, dt \right)^{1/p},$$

which is equivalent to requiring $\sum |a_n|^2 < \infty$ when $p = 2$. The space D^∞ consists of the space of Dirichlet series as above with $\|f\|_\infty := \sup\{|f(s)| : \sigma = \operatorname{Re} s > 0\} < \infty$. Then the Bohnenblust-Hille theorem [2] takes the form

Theorem: *The infimum of ρ such that $\sum_{n=1}^{\infty} |a_n| n^{-\rho} < \infty$ for every $\sum_{n=1}^{\infty} a_n n^{-s}$ in D^∞ equals* $1/2$.

For $k \geq 1$, let D_k^∞ denote the subspace of D^∞ consisting of $f(s) = \sum_{n=1}^{\infty} a_n n^{-s}$ such that $a_n = 0$ whenever the number of prime divisors of n exceeds k. If $(E, \|\cdot\|)$ is a Banach space of Dirichlet series, the isometric Bohr abscissa and the isomorphic Bohr abscissa are respectively defined as

$$\rho_1(E) = \min \left\{ \sigma \geq 0 : \sum_{n=1}^{\infty} |a_n| n^{-\sigma} \leq \|f\| \ \text{ for all } f \in E \right\},$$

and

$$\rho(E) = \inf \left\{ \sigma \geq 0 : \exists\, C_\sigma \in (0, \infty) \ \text{ such that } \sum_{n=1}^{\infty} |a_n| \|n^{-\sigma} \leq C_\sigma \|f\| \text{ for all } f \in E \right\}.$$

By using a number of recent developments in this topic (some of them related to the hypercontractivity properties of the Poisson kernel), the authors in [1] obtained among others the following results:

(1) If $1 \le p < \infty$, then $\rho(D^p) = 1/2$, but this value is not attained. For $p = \infty$, this is equivalent to determining the maximum possible width of the strip of uniform, but not absolute, convergence of Dirichlet series (see Theorem).

(2) $\rho(D^\infty) = 1/2$, and this value is attained. So $\sum_{n=1}^\infty |a_n| n^{-1/2} \le C\|f\|_\infty$ for some absolute constant C (see Theorem).

(3) Let $p \in [0,1]$. Every $f(s) = \sum_{n=1}^\infty a_n n^{-s} \in D^\infty$ satisfies $\sum_{n=1}^\infty |a_n n^{-\sigma}|^p < \infty$ whenever $\sigma \ge \sigma_0 := 1/p - 1/2$. If $\sigma < \sigma_0$, there is $f \in D^\infty$ such that the last sum is infinite.

(4) $\rho(D_k^\infty) = 1/2 - 1/(2k)$, and it is attained.

(5) $\rho_1(D_1^\infty) = 0$.

(6) $1.5903 < \rho_1(D_2^\infty) < 1.5904$.

(7) $1.585 < \log 3/\log 2 \le \rho_1(D^\infty) \le 1.8154$. In particular, $\sum_{n=1}^\infty |a_n| n^{-2} \le \|f\|_\infty$.

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PT-02

On Univalent Harmonic Mappings

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In this lecture, we plan to consider certain basic issues concerning the class $\mathcal{H}$ of sense-preserving harmonic functions $f = h + \overline{g}$ defined in the unit disk $|z| < 1$ and normalized so that $h(0) = 0 = h'(0) - 1$ and $g(0) = 0$, where h and g are analytic in the unit disk. In the first part of the lecture, we review a number of known results and open problems including some recent advances concerning harmonic analog of number of problems on conformal mappings. As applications, we study the harmonic sections (partial sums)

$$s_{n,n}(f)(z) = s_n(h)(z) + \overline{s_n(g)(z)}$$

of $f = h + \overline{g} \in \mathcal{H}$, where $s_n(h)(z) = z + \sum_{k=2}^n a_k z^k$ and $s_n(g)(z) = \sum_{k=1}^n b_k z^k$ denote the n-th partial sums of $h(z) = \sum_{k=1}^\infty a_k z^k$ and $g(z) = \sum_{k=2}^\infty b_k z^k$, respectively.

Some open problems will be discussed.

The lecture is based on a number of joint works with Shaolin Chen, Sergey Yu. Graf, Liulan Li, Sairam Kaliraj, Jinjing Qiao and Victor Starkov.

CMV matrices, Direct and Inverse problems, Applications

PT-03

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In this talk we will analyze matrix representations of the multiplication operator for probability measures supported on the unit circle. In particular, we will focus our attention on the CMV matrix, with a special emphasis on the spectral linear perturbations for the corresponding measure. The study of the direct and inverse Darboux transformations of CMV matrices will be studied.

Some applications to integrable systems will be also discussed.

Sobolev orthogonal polynomials on the unit circle and coherent pairs of measures of the second kind

PT-04

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A pair of non trivial probability measures (μ_0, μ_1), both supported on the unit circle, is known as a coherent pair of measures on the unit circle if the corresponding sequences of monic orthogonal polynomials $\{\Phi_n(\mu_0; z)\}_{n\geq 0}$ and $\{\Phi_n(\mu_1; z)\}_{n\geq 0}$ satisfy the relation $n\Phi_{n-1}(\mu_1; z) = \Phi'_n(\mu_0; z) + \rho_n \Phi'_{n-1}(\mu_0; z)$, $n \geq 1$. We refer to a pair of non trivial probability measures (μ_0, μ_1) supported on the unit circle as a *coherent pair of measures of the second kind* on the unit circle if the corresponding sequences of monic orthogonal polynomials satisfy $n^{-1}\Phi'_n(\mu_0; z) = \Phi_{n-1}(\mu_1; z) - \chi_n \Phi_{n-2}(\mu_1; z)$, $n \geq 2$. It turns out that there are more interesting examples of pairs of measures on the unit circle with this latter coherency property. The main objective in this contribution is to show how one can determine such pairs of measures. Properties of the orthogonal polynomials with respect to the Sobolev inner products associated with coherent pairs of measures of the second kind are also explored.

(This is a joint work with F. Marcellán.)

An extension problem for the sublaplacian on the Heisenberg group

PT-05

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There are several ways of defining fractional powers of the sublaplacian on the Heisenberg group H^n and one of them is by solving an elliptic differential equation on the one dimensional extension of H^n. In this method, fractional powers of the sublaplacian occur as the Neumann boundary values of solutions of the extended equation. We make use of this connection to prove a trace Hardy inequality for fractional powers of the sublaplacian from which Hardy type inequality can be deduced.

PT-06

Hypergeometric Functions in several variables

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Hypergeometric functions for symmetric matrices were introduced in the 1950's by C. Herz, building on earlier work of S. Bochner for Hermitian matrices. These functions have found applications in several areas, including a) in number-theory, to the problem, first investigated by C. Siegel, of lattice point counting for matrices, b) in statistics, to the study of non-central distributions, c) in physics, to exactly solvable models and random matrix theory.

In an influential though unpublished manuscript I. G. Macdonald developed a theory of multivariate hypergeometric functions depending on a parameter, which simultaneously generalizes the symmetric and Hermitian cases and many others besides. However key results of this more general theory have remained conjectural for over 25 years. I will describe recent work with G. Olafsson that proves several conjectures of Macdonald, and which serves to put the theory on a more solid footing.

Among other results we obtain sharp kernel estimates that allow us to establish a rigorous theory of the Fourier and Laplace transforms in this setting. This opens the door for several future developments in the associated harmonic analysis, some of which we treat, including a version of the Paley-Wiener theorem, the construction of multivariate hypergeometric functions via the Laplace and inverse Laplace transforms, and an extension of the Ramanujan master theorem.

PT-07

Convexity of Spherical Bernstein-Bezier Patches and Circular Bernstein-Bezier Curves

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Bernstein-Bezier curves and Bernstein Bezier patches play an important role in reconstructing curves and surfaces from scattered data. Scattered data approximation is an important area of research. P. Alfeld, M. Neamtu and L.L. Schumaker [2] introduced circular Bernstein-Bezier polynomials. In 1996, the same authors [3] studied Bernstein-Bezier polynomials on spheres and sphere-like surfaces. In 1991, Dahmen [1] had studied the convexity of Bernstein-Bezier polynomials. In 1995, He [4] had studied the approximation theoretic aspects of shape criteria of such polynomials over simplexes.

The object of this paper is to discuss the criteria of convexity of spherical Bernstein-Bezier patches, circular Bernstein-Bezier curves and homogeneous Bernstein-Bezier polynomials.

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On a Degenerate Algebraic Riccati Equation

PT-08

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The existence of solutions to a degenerate algebraic Riccati equation, associated to an optimal control problem with infinite time horizon, is studied. Under some assumptions on the control system, we can select a solution to this equation providing a feedback control law which can stabilize the system.

Further extensions to the Bohr inequality

PT-09

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The classical Bohr inequality deals in finding the largest radius r, $0 < r < 1$, such that $\sum_{n=0}^{\infty} |a_n| r^n \leq 1$ holds whenever $|\sum_{n=0}^{\infty} a_n z^n| \leq 1$ in the unit disk $\mathbb{U}$ of the complex plane. The exact value of this largest radius, known as the *Bohr radius*, has been established to be $1/3$. Thus $d\Big(\sum_{n=0}^{\infty} |a_n z^n|, |a_0|\Big) \leq d(f(0), \partial\mathbb{U})$ for every analytic self-map f of the unit disk, where d is the Euclidean distance, and $|z| \leq 1/3$.

We find the Bohr radius for certain power series in $\mathbb{U}$. The Bohr radius is also studied for analytic functions from $\mathbb{U}$ into specified domains Ω, in particular, when Ω is a concave wedge-domain. The analogous Bohr radius is also studied for harmonic and log-harmonic mappings in $\mathbb{U}$.

The Bohr phenomenon which is described in terms of the Euclidean distance will be further investigated using the spherical chordal metric and the Poincare metric.

Orthogonal Polynomials Everywhere

PT-10

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This is a general talk about several concrete problems whose formulation does not involve orthogonal polynomials but orthogonal polynomials play a central role in their solution.

PT-11

Integrable Systems, Orthogonal Polynomials and Random Matrices

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In this talk I shall discuss the relationship between integrable systems, in particular the Painlevé equations and discrete Painlevé equations, orthogonal polynomials with respect to semi-classical weights, which are generalizations of the classical weights and random matrices.

It is well-known that orthogonal polynomials satisfy a three-term recurrence relation. I will show that for some semi-classical weights the coefficients in the recurrence relation can be expressed in terms of Hankel determinants, which are Wronskians, that also arise in the description of special function solutions of Painlevé equations. The determinants arise as partition functions in random matrix models and the recurrence coefficients satisfy a discrete Painlevé equation. The semi-classical orthogonal polynomials discussed will include a generalization of the Freud weight and an Airy weight.

Invited Talks

Zeros of Bessel Function Derivatives

IT-01

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We prove that for $\nu > n-1$ all zeros of the nth derivative of the Bessel function of the first kind J_ν are real. Moreover, we show that the positive zeros of the nth and $(n+1)$th derivative of Bessel function of the first kind J_ν are interlacing when $\nu \geq n$ and n is a natural number or zero. Our methods include the Weierstrassian representation of the nth derivative, properties of the Laguerre-Pólya class of entire functions, and the Laguerre inequalities. Some similar results for the zeros of the first and and second derivative of the Struve function of the first kind $\mathbf{H}_\nu$ are also proved. These results generalize and complement some classical results on the zeros of Bessel and Struve functions of the first kind. Some conjectures and open problems related to Hurwitz theorem on the zeros of Bessel functions are also proposed, which may be of interest for further research.

(The talk is based on the paper : Á Baricz, C.G. Kokologiannaki, T.K. Pogány, Zeros of derivatives of Bessel and Struve functions, arXiv:1602.04295.)

Exceptional Orthogonal Polynomials

IT-02

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Exceptional orthogonal polynomials are families of complete orthogonal polynomials that arise as eigenfunctions of a Sturm-Liouville problem, which differ from the classical families of Hermite, Laguerre and Jacobi in that there is a finite number of gaps in their degree sequence. Despite the "missing" degrees, the remaining polynomials still span a complete basis of a weighted L_2 space, and the orthogonality weight is a rational modification of a classical weight. We will briefly review the main results in the theory of exceptional orthogonal polynomials (classification, position of their zeros, recurrence relations etc.), with emphasis on the similarities and differences with classical polynomials. We will also discuss their numerous applications in mathematical physics, which range from exact solutions to Schrodinger's equation in Quantum Mechanics to rational solutions of nonlinear integrable equations of Painlevé type.

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IT-03

Gamma Functions and Complex Analysis

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It is well known that complex analysis can be an elegant tool for solving problems in various areas of mathematics. In this talk I shall give examples of how techniques and classes of analytic functions enter in problems in the area of special functions: Contour integration arguments give information on the behaviour of the remainders in asymptotic expansions of logarithms of gamma function. The so called Nevanlinna-Pick functions play a crucial role in the investigation of inverses of gamma function and also in the median of the gamma distribution.

IT-04

Fragmentation-coagulation equations with diffusion

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In recent years new results concerning classical solvability of fragmentation- coagulation equations has been proved [1, 2]. In the present talk we discuss possibilities of extension of these results to fragmentation-coagulation equations with space diffusion, linking them with the linear theory developed in [3].

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Properties of generalized Freud polynomials

IT-05

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We consider the semi-classical generalized Freud weight function $w_\lambda(x;t) = |x|^{2\lambda+1}\exp(-x^4 + tx^2)$, $x \in \mathbb{R}$, with $\lambda > -1$ and $t \in \mathbb{R}$ parameters. The closed form expression for the recurrence coefficient obtained in earlier joint work with A. Kelil allow the investigation of properties of the monic polynomials that are orthogonal with respect to the generalized Freud weight $w_\lambda(x;t)$. We derive a second-order linear ordinary differential equation and a differential-difference equation satisfied by these generalized Freud polynomials and then analyze the asymptotic behavior of the generalized Freud polynomials in two different contexts. Firstly, we obtain asymptotic results for the polynomials when the parameter t involved in the semiclassical perturbation of the weight tends to $\pm\infty$. Next, we consider the asymptotics of the coefficient in the three-term recurrence relation satisfied by the generalized Freud polynomials as the degree n tends to infinity and investigate the asymptotic behavior of the polynomials themselves as the degree increases. We show that unique, positive solutions of the nonlinear difference equation satisfied by the recurrence coefficients exist for all $t \in \mathbb{R}$ but that these solutions are very sensitive to the initial conditions. We also prove various properties of the zeros of generalized Freud polynomials.

Convolutions with harmonic strip mappings

IT-06

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We prove results concerning the convolution of univalent harmonic convex mappings provided that the convolution is locally univalent and sense preserving. In particular, let f_k (where $k = 1, 2$) be univalent harmonic functions that are shears of the analytic map $h_k - g_k = \frac{1}{2}\ln\left(\frac{1+z}{1-z}\right)$ with dilatation $\omega_k = e^{i\theta_k}z^k$. If the convolution $f_1 * f_2$ is locally one-to-one and sense-preserving, then $f_1 * f_2 \in S_H^O$ is convex in the direction of the real axis.

IT-07

Generalized typically real functions

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Let $f(z) = z + a_2 z^2 + \cdots$ be regular in the unit disk and real valued if and only if z is real and $|z| < 1$. Then $f(z)$ is said to be typically real function. Rogosinski [4] has shown the necessary and sufficient condition for a regular function to be typically-real. The main purpose of the paper is consideration of the generalized typically-real functions defined via the generating function of the generalized Meixner-Pollaczek polynomials

$$G^{\lambda}(x;\theta,\psi;z) = \frac{1}{(1-ze^{i\theta})^{\lambda-ix}(1-ze^{i\psi})^{\lambda+ix}} = \sum_{n=0}^{\infty} P_n^{\lambda}(x;\theta,\psi)z^n, \ |z|<1.$$

The generalized class is denoted by $\mathcal{T}^{p,q}$ and defined as follows. For $-1 \leq p,q \leq 1$ let $\mathcal{T}^{p,q}$ denote the class of generalized typically-real functions [1, 2, 3], i.e. the class of functions of a form

$$f(z) = \frac{1}{2\pi}\int_0^{2\pi} \frac{zd\mu(\theta)}{(1-pze^{i\theta})(1-qze^{-i\theta})},$$

where $|z| < 1$, and $\mu(\theta)$ is the unique probability measure on the interval $\langle 0, 2\pi\rangle$.

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IT-08

Differential Subordinations and Superordinations for Analytic Functions

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We show some recent results obtained by the author involving different classes of analytic differential and integral operators that preserve the subordination and the superordination. *Sandwich-type results* for a wide class of generalized *Briot-Bouquet* differential operators, and for generalized *Alexander-Bernardi-Linvingston* integral operators are presented, which generalize and extend many well-known classical results in this area. Remark that all these theorems and consequences are sharp, that means all the bounds (in the sense of subordination) are the best possible.

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What can the three term recurrence relation tell us about orthogonal polynomials?

IT-09

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One of the most characteristic properties of orthogonal polynomials, besides the orthogonality itself, is the fact that every system of orthogonal polynomials satisfies a three term recurrence relation of a very specific form. This relation is in fact an abstract consequence of orthogonality and the fact that the orthogonal functions are polynomials. Now, it is a somewhat lesser known fact, one that frequently elicits surprise and interest among those not previously conversant with orthogonal polynomials, that in fact the converse is true. If a sequence of polynomials satisfies a three term recurrence relation of the specific form referred to above, then in fact these polynomials are orthogonal polynomials. Assuming without loss of generality that our polynomials are monic polynomials, the three term recurrence relation in question can be written in a form that involves two real sequence as coefficients. These two sequences determine the sequence of orthogonal polynomials completely and in theory, contain all the properties of system of polynomials. Thus, for example, in his pioneering work on continued fractions, Stieltjes essentially proved that the zeros of all of the orthogonal polynomials form a bounded set if and only if both sequence are bounded. In this talk, I will survey many of the significant results along these lines, results which are attributed to many great names, such as Stieltjes, Hausdorff, Carleman, M.G.Krein.

IT-10

Dunkl Processes: Relaxation Asymptotics and Jump Dynamics

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Dunkl processes are the Markov processes obtained from using the Dunkl Laplacian as a semigroup generator. Due to a difference term present in the Dunkl Laplacian, the evolution of the probability law of the process is non-local, that is, the process makes spontaneous jumps given by the action of a reflection group. We study the long-time asymptotics of the probability law and the mechanisms that drive them. In addition, we investigate the jumps of the process on their own and study their behavior in time.

(This is joint work with M.Katori (Chuo U.) and S. Miyashita (U. Tokyo).)

IT-11

Logarithmic convexity and concavity of generalized hypergeometric functions with respect to multiple parameter shifts

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Given a vector $\mathbf{a}$ and a scalar μ define $\mathbf{a}+\mu$ as $(a_1+\mu, a_2+\mu, \ldots, a_p+\mu)$. In the talk we discuss the logarithmic convexity and concavity of the function

$$\mu \to f(\mu; x) = \phi(\mu)\, {}_pF_q\left(\begin{matrix} \mathbf{a}_1, \mathbf{a}_2+\mu \\ \mathbf{b}_1, \mathbf{b}_2+\mu \end{matrix} \middle| x \right),$$

where ${}_pF_q$ is the generalized hypergeometric function and

$$\phi(\mu) \in \left\{ 1, \prod_{a_i \in \mathbf{a}_2} \Gamma(a_i+\mu), \frac{1}{\prod_{b_i \in \mathbf{b}_2} \Gamma(b_i+\mu)}, \frac{\prod_{a_i \in \mathbf{a}_2} \Gamma(a_i+\mu)}{\prod_{b_i \in \mathbf{b}_2} \Gamma(b_i+\mu)} \right\}.$$

Here $\mathbf{a}_i$, $\mathbf{b}_i$ are real vectors of lengthes p_i and q_i, respectively, with $p = p_1 + p_2$, $q = q_1 + q_2$. We also consider the power series coefficients of the generalized Turánian

$$f(\mu+\alpha; x) f(\mu+\beta; x) - f(\mu; x) f(\mu+\alpha+\beta; x)$$

and connection to Laguerre-Pólya class of entire functions. We further mention generalizations to series with generic terms involving product ratios of gamma functions and certain conjectures for combinatorial polynomials arising in these investigations.

(The results presented in the talk have been obtained jointly with S.I. Kalmykov. Financial support of the Ministry of Science and Education of the Russian Federation (under project 1398) is acknowledged.)

Some Aspects of Harmonic Univalent Map

IT-12

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We present many new results including area distortion inequalities, with sharp constants, of some classes of orientation preserving harmonic mappings such as the class of harmonic univalent maps onto the disk and the class of orientation preserving BMOH maps.

An Eclectic tour of Gamma Functions

IT-13

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The lecture is a historical guided tour through nearly three hundred years of the development of the gamma function since its inception in 1729 in a letter from Euler to Goldbach seeking an analytic interpolation of the factorial. The function has been subjected to intense research owing to its importance in analytic number theory, mathematical physics and the distinguished position it occupies in the theory of special functions. Some results obtained in the last few years will be discussed towards the end of the lecture.

On Quasi-Optimization Problems

IT-14

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We discuss the solutions of quasi-variational inequality problem in which the constraint map is a non-self set valued map. As application, quasi-optimization problem will be studied.

M-operators and some characterizations

IT-15

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A real square matrix A whose off-diagonal entries are nonpositive is called an (invertible) M-matrix if A is invertible and the entries of the inverse are nonnegative. More than fifty characterizations have been obtained for a matrix to be an M-matrix. In this talk, we present some recent results that characterize when an operator is an M-operator. A brief mention will be made on the case of singular M-matrices (and their extensions).

(Joint work with A. Kalauch (TU Dresden) and S. Lavanya (PhD student, IIT Madras).)

IT-16

Homogenization of a Hyperbolic equation in a Composite Media

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In this talk, we study homogenization of a hyperbolic equation defined in a composite media consisting of two highly contrasting materials. We obtain the limit system using the method of two-scale convergence. This is a method developed in 1990's to study homogenization problems, but it is a very general convergence which is very useful. We give a brief introduction to two-scale convergence as well.

IT-17

Applications of Hamilton-Jacobi equations in Shape from Shading

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Hamilton-Jacobi equations have wide applications in numerous fields of science such as classical mechanics and geometrical optics in physics. In this talk we emphasize upon both theoretical and numerical perspectives for this first order non-linear partial differential equations especially focussing on the application in the shape from shading i.e., to recover the shape of 3-dimensional object from 2-dimensional information.

IT-18

An Operator Theoretic Treatment for an Inverse Problem in PDE

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Many of the inverse problems in PDE are ill-posed, in the sense that small perturbations in the data can lead to large deviations in the solution. In such cases, certain regularization methods have to be applied for obtaining stable approximate solutions for the problems. In this talk, I am interested in a particular class of inverse problems in PDE, the so called *parameter identification problems*. More specifically, I am interested in obtaining approximations for the unknown parameter function $q(\cdot) \in H^1(\Omega)$ appearing in the elliptic PDE

$$-\nabla.(q\nabla u) = f \quad \text{in} \quad \Omega,$$

satisfying the boundary condition

$$q\frac{\partial u}{\partial \nu} = g \quad \text{on} \quad \partial\Omega,$$

where Ω is a bounded domain in $\mathbb{R}^d$, $f \in L^2(\Omega)$ and $g \in H^{-\frac{1}{2}}(\partial\Omega)$, when the data u varies over $W^{1,\infty}(\Omega)$. The weak formulation of the above problem as the problem of solving an operator equation of the form

$$T_u(q) = \Phi,$$

where, T_u is a compact operator from $H^1(\Omega)$ into its dual $[H^1(\Omega)]^*$. For obtaining regularized approximations for q when the available data is z with $\|u - z\|_{W^{1,\infty}(\Omega)} \leq \delta$ for some known noise level $\delta > 0$, we apply Tikhonov regularization and its finite dimensional realizations based on projection methods. The adopted procedure is simpler than some of the existing methods in the literature.

(This talk is based on a recently accepted paper (*A linear regularization method for a nonlinear parameter identification problem*, Journal of Inverse and Ill-Posed Problems) with my PhD student Samprita Das Roy.)

Local polynomial convexity of certain classes of surfaces with degenerated CR-singularity

IT-19

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Pascal Thomas introduced a class of cubic homogeneous cubic polynomial in z and $\bar{z}$, namely $p(z,\bar{z}) = z^2\bar{z} + \epsilon z\bar{z}^2 + \frac{\epsilon^2}{3}\bar{z}^3, \epsilon \in \mathbb{C}$, while giving examples of three totally-real planes in $\mathbb{C}^2$ whose pairwise union is locally polynomially convex at the origin but polynomial hull of the union contains interior. The above class of graphs has a degenerated CR-singularity at the origin. We argue that the local polynomial convexity of the above class of graphs at the origin is completely determined by the parameter ϵ. In the most cases we use a proper holomorphic map from $\mathbb{C}^2$ to $\mathbb{C}^2$ to pull back a graph of our considerations to union of three transverse totally-real planes. In the final part we will discuss local polynomial convexity of the surfaces viewing locally as graphs whose leading homogeneous term is of the above form.

Module Approach to Operator Theory

IT-20

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We will begin by briefly describing some of the reasons to be interested in Hilbert module approach to operator theory. Then we will review some recent results and developments in function theory and (multivariable) operator theory. Along the way, we will discuss a list of examples and (wild) conjectures.

Short Talks

Frequency Truncation Method for Symmetrizable Hyperbolic Systems ST-01

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Quasilinear symmetric and symmetrizable hyperbolic system has a wide range of applications in engineering and physics including unsteady Euler and potential equations of gas dynamics, inviscid magnetohydrodynamic (MHD) equations, shallow water equations, and Einstein field equations of general relativity. In the past, the Cauchy problem of smooth solutions for these systems has been studied by several mathematicians using semigroup approach and fixed point arguments (see [1, 2, 3] for example). In a recent paper [3], the authors established the local solvability of symmetric hyperbolic systems using two different methods, viz. local solvability of symmetrizable hyperbolic system in uniformly local Sobolev spaces introduced by Kato [1], using a frequency truncation method. The new method we present here are motivated by applications to control theory and stochastic analysis.

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ST-02

Symmetries of generalized Laplace and Dirac operators

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We consider a generalization of the classical Laplace operator, which includes the Laplace-Dunkl operator defined in terms of the differential-difference operators associated with finite reflection groups called Dunkl operators. For this Laplace-like operator, we determine a set of symmetries, which are generalized angular momentum operators which commute with it. Moreover, we present the algebraic relations for the symmetry algebra. In this context, the generalized Dirac operator is then defined as a square root of our Laplace-like operator realized in the framework of Clifford analysis. We explicitly determine a family of graded operators which commute or anti-commute with our Dirac-like operator depending on their degree. The algebra generated by these symmetry operators is shown to be a generalization of the standard angular momentum algebra and the recently defined higher rank Bannai-Ito algebra.

ST-03

Reciprocity Theorems Involving the q-Gamma Function

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In one of his notebooks, Ramanujan stated but did not prove an identity for a ratio of gamma functions involving two separate variables. Such an identity was referred to as a reciprocity theorem due to the symmetry relations between the variables. The two variable result was later proved and generalized to several variables by Berndt and Koukoulopoulos in 2006. In this work we state and prove similar reciprocity theorems for ratios of $q-$gamma functions involving two and more variables.

Multichannel transmission based on prolate spheroidals

ST-04

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Given a positive number a let $W(a)$ be the Paley-Wiener class of entire functions $f : \mathbb{C} \to \mathbb{C}$ such that $\int_{\infty}^{\infty} |f(t)|^2 dt < \infty, \exists_{K>0} \forall_{z\in\mathbb{C}} |f(z)| K e^{a|z|}$ endowed with the inner product

$$< g, h >= \int_{\infty}^{\infty} g(t)\overline{h(t)}dt, \quad g, h \in W(a).$$

It is well-known that $W(a)$ is a reproducing kernel Hilbert space of functions of the form

$$f(t) = \int_{-a}^{a} Y(\omega) e^{i\omega t} d\omega,$$

where $Y \in L_2(-a, a)$ and $i = \sqrt{-1}$. The reproducing kernel is explicitly given by

$$\mathbb{C}^2 \ni (x, y) \mapsto K_a(x, y) = \begin{cases} \frac{\sin(a(x-y))}{\pi(x-y)} & \text{if } \ x \neq y, \\ 0 & \text{otherwise.} \end{cases}$$

In technical sciences functions in $W(a)$ are called bandlimited signals (corresponding to the bandwidth $B = \frac{a}{2\pi}$). We'll focus on observing functions and their approximations on the interval $[-\tau, \tau]$ taking the $L_2(-\tau, \tau)$-norm to measure errors,

$$\|f\| = \left(\int_{-\tau}^{\tau} |f(t)|^2 dt \right)^{1/2}.$$

Prolate spheroidal wave functions are eigenfunctions of the integral operator

$$L_2(-\tau, \tau) \ni g \mapsto \int_{-\tau}^{\tau} K_a(\cdot, s) f(s) ds,$$

whose eigenvalues are arranged into a decreasing sequence $\{\lambda_k\}_{k=0}^{\infty}$ convergent to zero. The functions in the eigenpairs (λ_k, ϕ_k) are orthogonal in $L_2(-\tau, \tau)$ and uniquely determined by the condition

$$\forall_k \ \ \phi_k(\tau) > 0 \wedge \|\phi_k\| = 1.$$

The pairs (λ_k, ϕ_k) continuously depend on a and τ. Actually, each λ_k depends only on $c = a\tau$. Moreover, each ϕ_k has a unique extension $\mathbb{C} \ni z \mapsto \phi_k(z)$ in $W(a)$ and the sequence $\{\phi_k\}$ is orthogonal in $L_2(-\infty, \infty)$ and linearly dense in $W(a)$. More information can be found in the literature [1, 2]. The prolate spheroidal wave functions are important in mathematics and have many interesting applications in physics and technical sciences, especially in signal processing. However, they are not so easy to determine numerically. Most computational method aim to find $\phi_j(x)$ for given values of $j \leq m$ and $x \in [-\tau, \tau]$. They are usually based on infinite expansions

$$\phi_j = \sum_{k=0}^{\infty} d_{j,k} F_k,$$

where F_k are some functions orthonormal either on $[-\tau, \tau]$ or $(-\infty, \infty)$ [3, 4, 5]. Such an approach is natural, and the numeric representation $\{d_{j,k}\}_{k=0}^{n_j}$ may serve for any x. However, the computed representations $\left\{\sum_{k=0}^{n_j} d_{j,k} F_k\right\}_{j=1}^{m}$ are usually far from being numerically orthonormal on $[-\tau, \tau]$. In this talk we'll show how to overcome this obstacle. We'll also show how to use prolate spheroidals in piecewise bandlimited multichannel transmission. The basic idea of this transmission is as follows:

- independent channels $1, 2, \ldots, d$ every 2τ seconds simultaneously transmit nonnegative integers $c_1, c_2, \ldots, c_d$ within a given range ($\{0, 1\}$ in typical situation);
- j-th channel is associated with the prolate spheroidal wave function ϕ_j corresponding to the bandwidth a of the transmission medium, $j = 1, 2, \ldots, d$;
- the analog signal $s = \sum_{k=1}^{d} c_k \phi_k$ is send to the receiver in the time period 2τ;
- a special hardware (receiver) computes $c_1, c_2, \ldots, c_d$ based on the formula $c_k = (s, \phi_k)$, where $(\cdot, \cdot)$ is the inner product in $L_2(-\tau, \tau)$.

We'll also show how to make the transmission smooth by forcing the signals to assume zeros at the transmission nodes. Numerical simulation will be presented to illustrate enormous resistance of the transmission to noise.

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ST-05

The Orthogonal Polynomial system on (-1,1) corresponding to a modified gegenbauer weight function

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The problem of determining the orthogonal polynomial sequence on $(-1, 1)$ corresponding to the modified Gegenbauer weight function of the form

$$w(x) = \frac{4}{\ell} \frac{(1-x^2)^{\frac{1}{\ell}-1}}{\left[(1+x)^{\frac{1}{\ell}} + (1-x)^{\frac{1}{\ell}}\right]^2}, \quad \ell > 1$$

is posed here. Knowledge of the said orthogonal polynomial sequence is required in the construction of Gaussian quadrature rule for integrals of the type $\int_{-1}^{1} f(x)w(x)dx$ which exhibit strong singularity at the end-points. Accurate evaluation of the integrals of this type are required in the context of variable resolution spectral discretization of global atmospheric flows.

Group Inverse Extensions of Certain M-matrix Properties

ST-06

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Let $\mathbb{R}^{n\times n}$ denote the space of all real matrices with n rows and n columns. A matrix $A \in \mathbb{R}^{n\times n}$ is called a $Z-matrix$ if the off-diagonal entries of A are non positive. A $Z-matrix$ can be written as $A = sI - B$, where $s \geq 0$ and $B \geq 0$. A $Z-matrix$ A is called an $M-matrix$ if $s \geq \rho(B)$, where $\rho(B)$ denotes the spectral radius of B. In this article, generalizations of certain $M-matrix$ properties are proved for the group generalized inverse. The proofs use the notion of proper splittings of some type or the other. First, the following results are proved:
Theorem: Let $A \in \mathbb{R}^{n\times n}$ with index 1. Let $F = A - AA^{\#}$ and $G = AA^{\#} - A^{\#}$ be proper splittings of F and G, respectively. Then $F^{\#}$ exists. Suppose that $AA^{\#} \geq 0$ and $F^{\#} \geq 0$. Then $G^{\#}$ exists and $G^{\#} \geq 0$.
Theorem: Let $A \in \mathbb{R}^{n\times n}$ such that $A^{\#}$ exists. Let $A = U - V$ be a pseudo regular splitting. Then the following statements are equivalent:
(i) $A^{\#} \geq 0$.
(ii) The real part of any nonzero eigenvalue of $U^{\#}A$ is positive.
(iii) Any nonzero real eigenvalue of $U^{\#}A$ is positive.

Next, a recently introduced notion of a $B_{\#}$-splitting is used in deriving certain results. Finally, applications in obtaining comparison results for the spectral radii of matrices are presented.

Synchrosqueezing Transform on a Hyperbolic Chirp

ST-07

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This paper addresses the behavior of wavelet and short time Fourier transform-based synchrosqueezing method on a hyperbolic chirp. Here we build on ideas from the synchrosqueezing theory of Daubechies, Lu and Wu, and we show that Cauchy wavelet transform-based synchrosqueezing is well adapted to deal with hyperbolic chirps. We have proved that the quality of the instantaneous frequency (IF) estimate on that type of signals is independent from the scale, while Fourier transform-based synchrosqueezing is independent from the frequency for the linear chirp. These results are illustrated throughout several numerical experiments.

ST-08

The Grüss inequality for unital 2-positive linear maps

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In a recent work, Moslehian and Rajić have shown that the Grüss inequality holds for unital n-positive linear maps $\phi : \mathcal{A} \to B(H)$, where $\mathcal{A}$ is a unital C^*-algebra and H is a Hilbert space, if $n \geq 3$. They also demonstrate that the inequality fails to hold, in general, if $n = 1$ and question whether the inequality holds if $n = 2$. In this talk, we provide an affirmative answer to this question.

ST-09

Absolutely minimum attaining Closed Operators

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We define and discuss properties of the class of unbounded operators which attain minimum modulus. We establish a relationship between this class and the class of norm attaining bounded operators and compare the properties of both. Also we define absolutely minimum attaining operators (possibly unbounded) and characterize injective absolutely minimum attaining operators as those with compact generalized inverse. We give several consequence, one of them is that every such operator has a non trivial hyper invariant subspace.

ST-10

Eigenvalues Estimates for Hadamard product of Hermitian Matrices

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The Schur theorem provides the global bounds for spectrum of the Hadamard product of two positive semi-definite matrices. We obtain lower and upper estimates for each eigenvalue of the Hadamard product of two Hermitian matrices.

ST-11

On certain q-series & Continued Fractions

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In the present work we have obtained some continued fraction representations for the ratio of $q-$hypergeometric series. These continued fraction representations generalize many classical results on continued fraction including some of those given by Ramanujan. We also derive some identities analogous to those of Ramanujan.

Some Variations on Montel's Theorem

ST-12

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The theory of normal families of meromorphic functions initiated by Paul Montel in 1907 now forms an integral part of function theory. In fact, this theory is responsible for many exciting advances in the area of complex dynamics, but there has also been many far reaching internal developments in the theory during the last over hundred years. My lecture is an attempt to illustrate how the developments have taken place and still continue to develop by concentrating on one particular result- The Montel's theorem: *If each member of a family of meromorphic functions on some domain omit three distinct values of the extended complex plane, then the family is normal.* In fact, I will try to explore some of the directions in which this result has been extended and generalized over a little less than hundred years. Also, I shall present some of my own contributions in this direction.

Composition Operators between Musielak-Orlicz Spaces

ST-13

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Let Ω_1 and Ω_2 be two non–empty sets and let $V(\Omega_1, \mathbf{C})$ and $V(\Omega_2, \mathbf{C})$ be two topological vector spaces of complex valued functions on Ω_1 and Ω_3, respectively, under pointwise vector space operations, where $\mathbf{C}$ denotes the field of all complex numbers. Suppose $\tau : \Omega_2 \mapsto \Omega_1$ is a mapping such that $f \circ \tau \in V(\Omega_2, \mathbf{C})$, whenever $f \in V(\Omega_1, \mathbf{C})$. Define a composition transformation $C_\tau : V(\Omega_1, \mathbf{C}) \mapsto V(\Omega_2, \mathbf{C})$ as

$$C_\tau f = f \circ \tau, \ f \in V(\Omega_1, \mathbf{C}).$$

If C_τ is continuous, then C_τ is called a composition operator induced by τ.

In this talk, we will discuss the boundedness of these operators between Musielak-Orlicz spaces.

(This talk is based on my joint work with Heera Saini, Yunan Cui, Henryk Hudzik and Lech Maligranda.)

Recent Developments in Planar Harmonic Mappings

ST-14

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In the present lecture we aim at providing basic information about planar harmonic mappings with some historical background and different directions in which presently research work is carried out by researchers in this area. Further, we present connections of such mappings with hypergeometric functions.

ST-15

Multi-penalty regularization in learning theory

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The aim of learning theory is to seek for an algorithm that, given a set of examples $\{(x_i, y_i)\}_{i=1}^n$, returns a function f such that $f(x)$ is an good estimate of the output y when a new input x is given. It is clear that the problem is ill-posed. In this talk, we discuss how to regularize this problem using multi-penalty regularization. We will then discuss the issue of convergence, error estimates and the appropriate choice to regularization parameter for the proposed method.

(This is a joint work with Abhishake)

ST-16

Hybrid Sheffer-Appell Polynomials

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One of the important classes of polynomial sequences is the class of Sheffer sequences. The class of Appell polynomial sequences, which is a subclass of Sheffer polynomial sequences is equally important. The Appell and Sheffer polynomial sequences arise in numerous problems of applied mathematics, theoretical physics, approximation theory and several other mathematical branches. In this work, the Sheffer and Appell polynomials are combined to introduce the hybrid Sheffer-Appell polynomials by using operational methods. The determinant form and other properties of the Sheffer-Appell polynomials are established. As particular cases of these polynomials, the Sheffer-Bernoulli and Sheffer-Euler polynomials are introduced and corresponding results for these polynomials are also obtained. The operational correspondence between the Appell and Sheffer-Appell polynomials is used to derive the results for the Sheffer-Appell polynomials. Certain results for the Hermite-Appell and Laguerre-Appell polynomials are also obtained. Examples of some members belonging to the hybrid Sheffer-Appell polynomials are considered and the graphs of certain members are drawn for suitable values of the indices.

ST-17

Inverse problems of Calderon type

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

Neighbourhoods of univalent functions

ST-18

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We first discuss some old and new results on neighbourhoods of univalent functions which are the motivation for the present research in the manuscript [1]. We introduce (rather we define) formally the concept of a *central function*. We prove that there exist central functions for the classes $Co(p)$ of concave univalent functions with pole at the point $z = p \in (0, 1)$. Further, we construct a generalized neighborhood of this central function such that the whole class $Co(p)$ is contained in such neighborhood. We also consider similar questions for the class of functions that are analytic and univalent in the unit disc and for some of its important subclasses.

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A Positive Spectral Gradient-Like Method for Large-Scale Nonlinear Monotone Equations

ST-19

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In this work, we proposed a combination of a positive spectral gradient-like method and projection method for solving nonlinear monotone equations. The spectral gradient-like coefficient is obtained using a convex combination of two different positive spectral coefficients. Under the monotonicity and Lipschitz continuity assumptions the method is shown to be globally convergent. We show the efficiency of the method numerically by comparing it with the existing methods.

A null controllability result for fully nonlinear evolution equations

ST-20

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We prove a null controllability result for the control system

$$y'(t) = Ay(t) + f(t, y(t)) + u(t), y(0) = x,$$

where $A : D(A) \subset X \to X$ is a possibly multi-valued operator, X is a separable Banach space, $f : [0, +\infty) \times X \to X$ is a given function and $u(\cdot)$ is a control taking values in the unit ball of X. More precisely, we find a control $u(\cdot)$ that steers x into the origin 0 in a finite time $T > 0$, by the corresponding solution of the evolution equation under consideration.

ST-21

Alternating Iterative Method for Rectangular Matrices

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Theory of matrix splittings is a useful tool for solving large sparse restangular/square singular/square nonsingular systems of linear equations, iteratively. When two matrix splittings are given, it is of interest to compare the spectral radii of the corresponding iteration matrices. This helps to arrive at the conclusion that which splitting should one choose so that one can reach at the desired solution of accuracy or at the exact solution in a faster way. In this direction, many comparison results are available in the literature even for rectangular case. However, in case of existence of many splittings of a given matrix, comparison of spectral radii is time consuming. Such a situation can be overcome by introducing another iteration scheme which converges to the same solution of interest in a much faster way. In this context, theory of alternating iterations for real rectangular matrices is proposed here by generalizing the work of Benzi and Szyld [3] and using the notion of proper splittings, which came into light in 1974 due to the pioneering works of Berman and Plemmons [4]. The main advantage of proper splittings is convergence of the iterative method to least square solution of minimum norm of a rectangular system of linear equations for some sub classes of these splittings (see [4], [6], [7], [8] and [9]) and reduces to usual splitting in case of nonsingular matrices. The salient contributions of the present work are mentioned hereunder.

(a) We first provide two comparison results which will help us in detecting a better splitting between two proper splittings.

(b) We then introduce the notion of alternating iterative scheme for rectangular matrices by using the Moore-Penrose inverse [2] and study its convergence theory.

(c) Finally, when two alternating iteration schemes for solving a same system of linear equations are available, it is of interest to know which one will converge faster, and is settled next by inclusion of a comparison result.

We hope that this work will provide useful insights into extending this approach and thus help in solving rectangular linear systems in a faster way. Applications of this theory to compute pagerank of a google matrix can be found in the recent article [5] while the numerical behavior of such methods is discussed in [1], both in nonsingular matrix setting.

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Abelian Theorem Involving Bessel Wavelet Transform

ST-22

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In this paper, the Abelian theorems involving Bessel wavelet transform is investigated and afterwards certain distributional results discussed by exploiting the theory of Hankel transform.

Semilocal convergence of a computationally efficient iterative method in Banach spaces under weak condition

ST-23

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In this article, we discuss the semilocal convergence of well established iterative method for solving nonlinear equations in Banach spaces under relaxed condition. The semilocal convergence of this scheme is established by using recurrence relations. We derive a system of recurrence relations for the method and then prove the existence and uniqueness result that shows the $R-$order of the method. Finally, numerical example is presented to validate the theoretical discussions.

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On some properties of extended Wright type hypergeometric function

ST-24

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In recent past, several interesting families of hypergeometric functions were investigated systematically. In the present talk, we introduce a new family of hypergeometric function and report several properties of this extended Wright type hypergeometric function.

γ-Hyperconnectedness in Fuzzy Topological Spaces

ST-25

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This paper introduces the notion of γ-hyperconnectedness in fuzzy topological space to show that it is completely independent to fuzzy hyperconnectedness in the sense of Miguel Caldas. The paper also presents some equivalence theorems linking the concept with regular open sets in this context. Applying this new effective idea we move forward one more step towards the difference between topological spaces and fuzzy topological spaces. We contemplate that this study may be applicable in parallel topology related to parallel circuit of electronic network and consequently in graph theory also.

Extension of Laguerre Transform and its Applications

ST-26

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Debnath[1] introduced the Laguerre transform and derived some properties. He also discussed the applications in study of heat conduction, oscillations of a very long and heavy chain with variable tension. Glaeske generalized Laguerre transform of one variable as Laguerre- Pinney transformation, Wiener-Laguerre transformation and derived its properties. In this talk, we discuss the extension of work of Debnath on Laguerre transform, which is defined as,

$$\mathcal{L}\{f(x,y)\} = F_n(\alpha,\beta) = \int_0^\infty \int_0^\infty e^{-(x+y)} x^\alpha y^\beta K_n^{(\alpha,\beta)}(x,y) f(x,y) dxdy,$$

where, $f(x,y)$ be a Riemann integrable function defined on the set $S = \mathbb{R}^+ \times \mathbb{R}^+, \alpha > -1, \beta > -1, n$ is non negative integer and $K_n^{(\alpha,\beta)}(x,y) = L_n^\alpha(x) L_n^\beta(y)$.

We also give some basic properties and its applications in special type of partial differential equations.

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ST-27 **On q–series, Split $(n+t)$–color partitions and 2–color F–partitions**

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Andrews [1] defined the two classes of generalized F–partitions: F–partitions and k–color F–partitions. For many q–series and Rogers–Ramanujan type identities, the bijections are established between F–partitions and $(n+t)$–color partitions. Recently $(n+t)$–color partitions have been extended to split $(n+t)$–color partitions by Agarwal and Sood [2]. The purpose of this paper is to study the k–color F–partitions as a combinatorial tool. The paper includes combinatorial proofs and bijections between split $(n+t)$–color partitions and 2–color F–partitions for some generalized q–series. Our results further give rise to infinite three way combinatorial identities in conjunction with some Rogers–Ramanujan type identities for some particular cases.

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ST-28 **Bounds for Radii of Starlikeness and Convexity of some Special Functions**

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In this work we consider some normalized Bessel, Struve and Lommel functions of the first kind. By using Euler-Rayleigh inequalities we obtain tight lower and upper bounds for the radius of univalence of these functions. Also by considering two different normalizations of Bessel and Struve functions we give some inequalities for the radii of convexity of the same functions. On the other hand we show that the radii of univalence of some normalized Struve and Lommel functions are exactly the radii of starlikeness of the same functions. In addition to that by using some ideas from Ismail and Muldoon's paper we present some new lower and upper bounds for the zeros of derivatives of some normalized Struve and Lommel functions. The Laguerre-Pólya class of entire functions plays an important role in our study.

Geometric properties of regular Coulomb wave functions

ST-29

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In this talk our aim is to present the radii of univalence, starlikeness and convexity of the normalized regular Coulomb wave functions for two different kinds of normalization. The key tools in the proof of our main results are the Mittag-Leffler expansion for regular Coulomb wave functions, and properties of zeros of the regular Coulomb wave functions and their derivatives. Moreover, by using the technique of differential subordinations we present some conditions on the parameters of the regular Coulomb wave function in order to have starlike normalized forms of the Coulomb wave function. An open problem for the zeros of the regular Coulomb wave functions is also stated which may be interest for further research.

(The talk is based on a joint work of Á. Baricz, M. Çağlar, E. Deniz, E. Toklu.)

Radii of starlikeness and convexity of a cross-product of Bessel functions

ST-30

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In this paper some geometric properties of the normalized form of the cross-product and product of Bessel and modified Bessel functions of the first kind are studied. For the cross-product and the product of three different normalization are investigated and for each of the six functions the radii of starlikeness and convexity are precisely determined by using their Hadamard factorization. Necessary and sufficient conditions are also given for the parameters such that the six normalized functions are starlike in the open unit disk, however the convex case is open for further research. The characterization of entire functions from the Laguerre-Pólya class via hyperbolic polynomials play an important role in this paper. Moreover, the interlacing properties of the zeros of the cross-product and product of Bessel functions and their derivatives are also useful in the proof of the main results.

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ST-31

A Spectral Gradient Conjugate Gradient Algorithms for Large-Scale Non-linear Systems of Equations

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In this paper, we proposed a new conjugate gradient algorithm for solving systems of large-scale non-linear equations. The algorithm is based on equating the classical conjugate gradient direction with the direction corresponding to the spectral gradient method. Using some derivative-free line search, we prove that under suitable conditions the proposed algorithm is globally convergent. Numerical comparisons show that the method is competative with some recent developed methods.

On logarithmic coefficients of close-to-convex functions

ST-32

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Let $\mathcal{S}$ denote the class of functions analytic and univalent (i.e. one-to-one) in the unit disk $\mathbb{D} = \{z \in \mathbb{C} : |z| < 1\}$ normalized by $f(0) = 0 = f'(0) - 1$. The logarithmic coefficients γ_n of $f \in \mathcal{S}$ are defined by $\log \frac{f(z)}{z} = 2\sum_{n=1}^{\infty} \gamma_n z^n$. In this talk, we discuss the sharp upper bounds for $|\gamma_3|$ when f belongs to the family of close-to-convex functions.

Contributory Talks

Duality Techniques on a class of functions defined by convolution with Gaussian hypergeometric functions

CT-01

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We use the duality principle and find conditions to characterize the starlikeness and convexity of the integral transform

$$V_\lambda(f)(z) = \int_0^1 \lambda(t)\frac{f(tz)}{t}dt$$

of functions f belonging to a class of functions defined by convolution with Gaussian hypergeometric functions.

(This talk is based on the following article:
S. K. Sahoo and N. L. Sharma, Duality techniques on a class of functions defined by convolution with Gaussian hypergeometric functions, J. Anal. **22** (2014), 145–155.)

Removable sets for Sobolev, Orlicz-Sobolev and weighted Orlicz-Sobolev spaces

CT-02

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In this talk, I will discuss about removable sets for Sobolev spaces, Orlicz-Sobolev spaces and some weighted version of Orlicz-Sobolev spaces. I will present the theories of removability of sets lying in a hyperplane and we will see that the removability of these sets is essentially determined by their thickness measured in terms of a concept of porosity.

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CT-03

Local Convergence of Super Halley's method under weaker condition on Fréchet derivative in Banach Spaces

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Super Halley's method is one of the most important iterative method for solving nonlinear equations in Banach spaces. It's local convergence analysis is established using either majorizing sequence or recurrence relations under various continuity conditions such as Lipschitz or Hölder using first/second order Fréchet derivatives. In this paper, an attempt is made to establish it's local convergence analysis under weaker continuity conditions on first order Fréchet derivative. This work generalizes the earlier work in this direction and it is observed that it is applicable to cases whether they either fail to converge or give smaller balls of convergence.

CT-04

Truncated spectral regularization method for source identification in an abstract Cauchy problem

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Abstract inverse source problem

$$\begin{aligned} u_t + Au = f(t), \quad 0 < t < \tau \\ u(0) = \phi_0, \quad u(\tau) = \phi_\tau \end{aligned}$$

is considered, when A is a densely defined self-adjoint coercive unbounded operator on a Hilbert space H. Following the procedure in Hasanov and Slodicka [1](2013), it can be seen that for $\phi_0, \phi_\tau \in D(A)$, the mild solution of the considered problem is of the form

$$f(t) = (e^{-\tau A} - I)^{-1} A \left(\phi_\tau - e^{-\tau A}\phi_0 - \int_0^\tau e^{-(\tau - s)A} g(s) ds \right) + g(t),$$

for any $g \in L^1([0,\tau]; H)$ with $\int_0^\tau S(\tau - s)g(s) \in D(A)$. Since A is an unbounded operator, small perturbations in ϕ_τ can lead to a large deviations in the mild solution f. To obtain a stable approximation of f, we consider the spectral regularization by truncation, namely as

$$f_\beta(t,\phi) = \int_\gamma^\beta \frac{\lambda}{e^{-\lambda\tau} - 1} dE_\lambda \phi - (e^{-\tau A} - I)^{-1} A \left(e^{-\tau A}\phi_0 - \int_0^\tau e^{-(\tau - s)A} g(s) ds \right) + g(t),$$

where $\{E_\lambda : \lambda \geq \gamma\}$ is the resolution of identity of the operator A and $\beta > \gamma$ with γ as a coefficient of coercivity of A. We carry out error analysis under a general condition on ϕ_τ, namely

$$\int_\gamma^\infty [\lambda h(\lambda)]^2 dE_\lambda \phi_\tau||^2 < \infty,$$

where $h : [\gamma, \infty) \to (0, \infty)$ is a monotonically increasing piecewise continuous function. Under this assumption, we prove

$$||f(t) - f_\beta(t)|| \leq O\left(\frac{1}{h(\beta)}\right), \quad 0 \leq t \leq \tau.$$

When the data ϕ_τ is noisy, that is, if we have ϕ_τ^ϵ in place of ϕ_τ with $||\phi_\tau - \phi_\tau^\epsilon|| \leq \epsilon$ for some $\epsilon > 0$, strategy of choosing the regularization parameter $\beta_\epsilon := \beta(\epsilon)$ has been suggested which yields an error estimate as a function of ϵ.

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Weighted Fractional composition operators on certain function spaces

CT-05

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In this paper we give some characterizations for the boundedness of the weighted fractional composition operator $D^{\beta}_{\varphi,u}$ from $\alpha-$bloch spaces into weighted type spaces by deriving the bounds of its norm. Also estimates for the essential norm are obtained which gives necessary and sufficient conditions for the compactness of the operator $D^{\beta}_{\varphi,u}$.

The Bounded Approximation Property for the Predual of the Weighted Space of Holomorphic Mappings on Banach Spaces

CT-06

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Let E be the complex Banach space and U be an open subset of E. The class of all complex valued holomorphic functions defined on U is denoted by $\mathcal{H}(U)$. Corresponding to a weight v(a strictly positive continuous function) defined on U, the weighted space of holomorphic functions is defined as

$$\mathcal{H}_v(U) = \{f \in \mathcal{H}(U) : ||f||_v = \sup_{x\in U} v(x)|f(x)| < \infty\}$$

The space $(\mathcal{H}_v(U), ||\cdot||_v)$ is a Banach space and B_v denotes its closed unit ball.

A weight v defined on an open balanced subset U of E is said to be *radial* if $v(tx) = v(x)$ for all $x \in U$ and $t \in \mathbb{C}$ with $|t| = 1$; and on E,it is said to be *rapidly decreasing* if $\sup_{x\in E} v(x)||x||^m < \infty$ for each $m \in \mathbb{N}_0$. Corresponding to a decreasing family $\mathcal{V} = \{v_n\}_{n\in\mathbb{N}}$ of radial rapidly decreasing weights on E, we consider the space $\mathcal{V}H(E)$ defined as

$$\mathcal{V}H(E) = \{f \in H(E) : \text{there exists some } n \in \mathbb{N} \text{ such that} ||f||_{v_n} = \sup_{x\in U} v_n(x)|f(x)| < \infty\}$$

which is endowed with the inductive limit topology τ_I. The predual of $\mathcal{V}H(E)$ is given by

$$\mathcal{V}G(E) = \{\phi \in \mathcal{V}H(E)' : \phi|\, B \text{ is } \tau_0- \text{ continuous for each } \tau_I- \text{ bounded set } B\}$$

where τ_0 denotes the topology of uniform convergence on compact subsets of E. We show that there is an $\mathcal{S}-$absolute decomposition for $\mathcal{V}G(E)$ with respect to the topology of uniform convergence on τ_I-bounded sets. Using this result, we characterize the bounded approximation property for the space E in terms of the bounded approximation property for $\mathcal{V}G(E)$.

CT-07 **Quasiconformal Extension of Meromorphic Functions with nonzero Pole**

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In this talk, we consider meromorphic univalent functions $f(z)$ in the unit disc with a simple pole at $z = p \in (0, 1)$ which have a $k-$quasiconformal extension to the extended complex plane $\mathbb{C}\cup\{\infty\}$ where $0 \leq k < 1$. We denote the class of such functions by $\sum_k(p)$. Here, a mapping $f : \mathbb{C}\cup\{\infty\} \to \mathbb{C}\cup\{\infty\}$ is called $k-$quasiconformal if f is a homeomorphism and has locally L^2- derivatives on $\mathbb{C}\backslash\{f^{-1}(\infty)\}$ (in the sense of distribution) satisfying $|\bar{\partial}f| \leq k|\partial f|$ a.e., where $\bar{\partial}f = \partial f/\partial\bar{z}$ and $\partial f = \partial f/\partial z$. We first prove an area theorem for functions in this class. Next, we derive a sufficient condition for meromorphic functions in the unit disc with a simple pole at $z = p \in (0, 1)$ belong to the class $\sum_k(p)$. Finally, we give a convolution property for functions in the class $\sum_k(p)$.

(This talk is based on the following article:
B. Bhowmik, G. Satpati and T. Sugawa, Quasiconformal extension of meromorphic functions with nonzero pole, Proc. Amer. Math. Soc. **144** (2016), no. 6, 2593–2601.)

CT-08 **The Distributional continuous Fractional generalized Hankel-Clifford Transformation**

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The main objective of this paper is to study the fractional generalized Hankel-Clifford transformation and some of their basic properties. Applications of the fractional generalized Hankel-Clifford transformation in solving generalized nth order linear non-homogeneous ordinary differential equations are given. The continuous fractional generalized Hankel-Clifford transformation, its inverse formula are also studied.

CT-09 **Open Ball centered at an invertible element of a Banach Algebra**

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The open ball centered at an invertible element a of a Banach algebra A, with radius $\frac{1}{||a^{-1}||}$, is contained inside the open set of all invertible elements, $G(A)$ in A. An invertible element a of a Banach algebra A is said to satisfy BOBP (Biggest Open Ball Property) if the boundary of the ball $B\left(a, \frac{1}{||a^{-1}||}\right)$ intersects the set of non invertible elements in A. We say a Banach algebra A satisfies BOBP if every a in $G(A)$ satisfies BOBP. We characterize all commutative Banach algebras that satisfy BOBP. We prove that all C^* algebras satisfy BOBP and give sufficient conditions for some more Banach algebras to satisfy the same.

Semilocal convergence of two step Kurchatov method for nondifferentiable operator

CT-10

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In this article, we present a new semilocal convergence analysis for the two step Kurchatov method. The main advantage of this method is that it does not need to evaluate any Fréchet derivative. The method includes extra parameters in the divided difference in order to ensure a good approximation to the first derivative in each iteration. The convergence analysis is established using recurrence relations which involved the first order divided differences satisfies the Lipschitz condition. We prove using recurrence relations a semilocal convergence in Banach spaces and also do a detailed study of the domain of parameters of the method.

Existence Results for Sobolev type fractional integro-differential equation with fractional nonlocal conditions

CT-11

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In this paper, we apply monotone iterative technique coupled with the method of lower and upper solutions to obtain the existence and uniqueness of the mild solution for the following Sobolev type fractional integro-differential equation with fractional nonlocal conditions in an ordered Banach space X:

$$
\begin{aligned}
&{}^{C}D^{q}[Bx(t)] = Ax(t) + f\left(t, x(t), \int_0^t k(t,s,x(s))ds\right), \quad t \in I = (0,T] \\
&{}^{L}D^{1-q}[Tx(0)] = x_0 + g(x(t)),
\end{aligned}
$$

where ${}^{c}D^{q}$ denotes the Caputo fractional derivative and ${}^{L}D^{q}$ denotes the Riemann-Liouville fractional derivative of order $q \in (0,1]$. $A : D(A) \subset X \to X$, $B : D(B) \subset X \to X$ and $T : D(T) \subset X \to X$ are linear operators. $\Omega = \{(t,s) : 0 < s \leq t < \infty\}$. $f : I \times X \times X \to X$, $k : \Omega \times X \to X$ and $g : C(I,X) \to X$ are given functions. The results are obtained using the theory of semigroup and Kuratowski measure of noncompactness. At last, an example is given to show the availability of main results.

CT-12 Approximate Controllability of Semilinear Fractional Stochastic System of Order $\rho \in (1, 2]$ with Nonlocal Conditions

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This paper is concerned with the approximate controllability of semilinear fractional stochastic system of order $\rho \in (1, 2]$ with nonlocal conditions. By using Sadovskii's Fixed Point Theorem with fractional calculus and stochastic analysis theory, we derive a new set of sufficient conditions for the approximate controllability of fractional stochastic system with nonlocal conditions under the assumption that the corresponding linear system is approximate controllable. Finally, an application to a fractional stochastic system with nonlocal initial conditions is provided to illustrate the feasibility of the obtained results.

CT-13 Kantorovich type modification of $q-$ Bernstein-Schurer operators

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The present paper deals with the Kantorovich type modification of $q-$Bernstein-Schurer operators to find an approximation process for integrable functions. The convergence of these operators is tested by utilizing the Korovkin's method of test functions. The approximation properties such as Voronovskaja type theorem and rate of convergence in terms of classical modulus of smoothness of second order are also studied. Finally we establish a approximation theorem in the weighted space of continuous functions.

CT-14 Data visualization by Rational fractal function based on function values

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This article proposes a rational fractal interpolation function (FIF) with three shape parameters based on function values only. The constructed FIF involves rational functions with numerators as cubic polynomials chosen according to the interpolation conditions and denominators as preassigned quadratic polynomials with three shape parameters. An upper bound of the uniform error of the rational cubic FIF with an original function in $\mathscr{C}^1$ is derived and the convergence is deduced. The parameters involved in the fractal functions are identified so as to solve certain constrained interpolation problems. We illustrate our interpolation scheme with some numerical examples.

$\{T, S\}$ Splittings of Rectangular Matrices Revisited

CT-15

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Let $\mathbb{R}^n$ denote the n dimensional real Euclidean space and $\mathbb{R}^{m\times n}$ denote the set of all real matrices of order $m \times n$. Let $A \in \mathbb{R}^{m\times n}$ be of rank r, let T be a subspace of $\mathbb{R}^n$ of dimension $s \leq r$ and let S be a subspace of $\mathbb{R}^m$ of dimension $m - s$. Then the splitting $A = U - V$ is called the $\{T, S\}$ splitting of A if $UT \oplus S = \mathbb{R}^m$. In this article, $\{T, S\}$ splittings of rectangular matrices are considered and derived certain convergence results. These results involve outer inverses (or $\{2\}$-inverses) with prescribed range and null space, of matrices emerge from the $\{T, S\}$ splittings. First, we prove the following convergence results:

Theorem: Let $A \in \mathbb{R}^{m\times n}$ be of rank r, let T be a subspace of $\mathbb{R}^n$ of dimension $s \leq r$ and let S be a subspace of $\mathbb{R}^m$ of dimension $m - s$, such that $AT \oplus S = \mathbb{R}^m$. Assume that $A = U - V$ is a $\{T, S\}$ splitting of A and $dim(T) \leq rank(U)$. Suppose that $A^{(2)}_{T,S}U \geq 0$ and $U^{(2)}_{T,S}V \geq 0$. Then $\rho(U^{(2)}_{T,S}V) = \dfrac{\rho(A^{(2)}_{T,S}U) - 1}{\rho(A^{(2)}_{T,S}U)} < 1.$

Theorem: Let $A \in \mathbb{R}^{m\times n}$ be of rank r, let T be a subspace of $\mathbb{R}^n$ of dimension $s \leq r$ and let S be a subspace of $\mathbb{R}^m$ of dimension $m - s$, such that $AT \oplus S = \mathbb{R}^m$. Assume that $A = U - V$ is a $\{T, S\}$ splitting of A and $dim(T) \leq rank(U)$. Suppose that $U^{(2)}_{T,S}V \geq 0$. Then $A^{(2)}_{T,S}V \geq 0$ if and only if $\rho(U^{(2)}_{T,S}V) = \dfrac{\rho(A^{(2)}_{T,S}V)}{1 + \rho(A^{(2)}_{T,S}V)} < 1.$

Finally, we prove comparison results for $\{T, S\}$ splittings.

Third Hankel Determinant for Generalized Sakaguchi functions

CT-16

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In this present investigation, we obtain the upper bound to the third Hankel determinant for the generalized Sakaguchi functions in the open unit disk using subordination.

Toeplitz Determinant for Some Subclasses of Analytic Functions

CT-17

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Let f be analytic in $\mathbb{D} = \{z : |z| < 1\}$ with $f(z) = z + \sum_{n=2}^{\infty} a_n z^n$. In this present investigation, we are finding the sharp bounds for the symmetric Toeplitz determinant for $T_2(2), T_2(3), T_3(2)$ and $T_3(1)$ for the functions belonging to a subclass $\mathcal{M}(\alpha)$.

CT-18 **Inverse Problems for Wave Equation in 3-D with under-determined Data**

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In [2], the author considered inverse problems for wave equation in 3-dimensions with source and receiver at the same point. There he proved unique determination of the zeroth order perturbation from the measured response under some assumption on the coefficient (since these problems are under-determined, additional assumptions on the coefficient are required for uniqueness). Motivated by this work, in this talk, we will present several problems but with source and receiver at distinct points.

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CT-19 **On Inverse Coefficient Estimates for Certain Starlike Functions**

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For $-1 \leq B < A \leq 1$, by $\mathcal{S}^*(A,B)$ denote the class of normalized analytic functions in $|z| < 1$ which satisfy the subordination relation $zf'(z)/f(z) \prec (1+Az)/(1+Bz)$ and let $\Sigma^*(A,B)$ be the corresponding class of meromorphic functions in $|z| > 1$. In this talk, we discuss about the estimate of the absolute value of the Taylor coefficients $a_n(-\lambda, f)$ of the analytic function $(f(z)/z)^{-\lambda}$ where $f \in \mathcal{S}^*(A,B)$ and $\lambda > 0$. Finally, we conclude this talk by determining the coefficient estimate for inverses of functions in the classes $\mathcal{S}^*(A,B)$ and $\Sigma^*(A,B)$.

CT-20 **Application of Semigroup theory for the Pure Fragmentation equation**

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The present work deals with the population balance equation considering only pure fragmentation using the semigroup theory of linear operators. The existence and uniqueness of nonnegative, strong solution is established via truncation approach of abstract Cauchy problem.

On Some Subclass of Harmonic Close-to-convex Mappings

CT-21

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In this presentation, we introduce a new subclass $\mathcal{W}^0_{\mathcal{H}}(\alpha)$ of harmonic close-to-convex mappings in the unit disk $\mathbb{D}$. First we prove the coefficient conjecture of Clunie and Sheil-Small for functions in the class $\mathcal{W}^0_{\mathcal{H}}(\alpha)$. We also derive a sufficient condition for f to belong to the class $\mathcal{W}^0_{\mathcal{H}}(\alpha)$. Further we consider growth theorem, convolution, convex combination properties for functions in the class $\mathcal{W}^0_{\mathcal{H}}(\alpha)$.

On Coefficient problem for bi-univalent analytic functions

CT-22

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Let $\mathcal{A}$ be the class of functions f analytic in the open unit disk $\mathbb{D} = \{z \in \mathbb{C} : |z| < 1\}$ and normalized by the conditions $f(0) = 0, f'(0) = 1$. The Koebe one-quarter theorem assures that the image of the unit disk $\mathbb{D}$ under every univalent function $f \in \mathcal{A}$ contains a disk of radius $1/4$. Thus every univalent function f has an inverse f^{-1} satisfying $f^{-1}(f(z)) = z(z \in \mathbb{D})$ and

$$f(f^{-1}(w)) = w \quad (|w| < r_0(f), r_0(f) \geq 1/4).$$

A function $f \in \mathcal{A}$ is said to be bi-univalent in $\mathbb{D}$ if f is univalent and f^{-1} has univalent analytic continuation to the unit disk $\mathbb{D}$. Here, in this paper, estimates for initial coefficients of Taylor-Maclaurin series of bi-univalent functions belonging to certain classes defined by subordination are obtained. Our estimates improve upon the earlier known estimates for second and third coefficient. The bound for the fourth coefficient is new. In addition, bound for the fifth coefficient is obtained for bi-starlike and strongly bi-starlike functions of order ρ and β respectively.

(This is a joint work with Prof. V. Ravichandran, Department of Mathematics, University of Delhi, Delhi.)

Pick functions involving triple gamma function

CT-23

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In this work some special functions involving triple gamma function are considered and is shown to have extension to Pick function. Interesting properties of the triple gamma function are also discussed.

CT-24

On perturbations of g-fractions and some related consequences

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We study two perturbations in the parameter sequence $\{g_k\}_{k=0}^{\infty}$ of a g-fraction and their effects on the mapping properties of some particular special functions that those g-fractions represent. In this context, we introduce what we term as *gap*-g-fraction. As a consequence we characterize a class of Pick functions using one of the perturbed g-fraction.

CT-25

On wavelet induced isomorphisms for joint $(d, -d)$-dilation wavelet and multiwavelet sets

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For a dyadic wavelet set W, Ionascu [1] obtained a measurable self- bijection on the interval [0,1), called the wavelet induced isomorphism of [0,1), denoted by $\tilde{h}_W$. Extending the result for a d-dilation wavelet set, we characterize a joint $(d, -d)-$dilation wavelet set, where $[d]$ is an integer greater than 1, in terms of wavelet induced isomorphisms. Its analogue for a joint $(d, -d)$-dilation multiwavelet set has also been provided.

In addition, denoting by $\tilde{h}_W^d$, the wavelet induced isomorphism associated with a $d-$dilation wavelet set W, we show that for a joint $(d, -d)$-dilation wavelet set W, the measures of the fixed point sets of $\tilde{h}_W^d$ and $\tilde{h}_W^{(-d)}$ are equal almost everywhere.

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CT-26

Iterative Approximation method with Averaged mapping for finite family of equilibrium problem and fixed point problem

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This paper aims to deal with an iterative method with averaged mapping to capture a common solution of a finite family of equilibrium problem and a fixed point problem of a finite collection of nonexpansive mappings in the setting of real Hilbert spaces. We prove that the sequences generated by the iterative scheme strongly converges to a common solution of the above said problems. Applications and numerical results are also given to illustrate the effectiveness and superiority of the proposed algorithm. The results presented in this paper are the extension and improvement of the recent results in the literature.

The wavelet packet transformation involving the fractional powers of Hankel-type integral transformation

CT-27

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The wavelet packet transformation involving the fractional powers of Hankel-type integral transformation is defined and discussed on its some basic properties. An inversion formula of this transformation is also obtained. Some examples are given.

Operators and Multipliers on Weighted Bergman Spaces

CT-28

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O. Blasco in [1] considered a weighted Bergman space using Dini-weight function. He proved that a linear operator T on weighted Bergman space to any Banach space X is bounded if and only if certain one parameter fractional derivative of a single X-valued analytic function satisfy some growth condition. In this paper, we use a three parameters fractional derivative of a single X-valued analytic function and provide an equivalent condition. In particular, we showed that if T is bounded, then using our result one can conclude much more than what has been achieved by Blasco. Our technique uses the Gaussian hypergeometric functions. Furthermore we supply some conditions on the parameters a, b and c under which the Gaussian hypergeometric function $F(a, b; c; z)$ are Dini-weight.

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Bounding inequalities for the generalized Voigt function

CT-29

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In this present paper, by applying several known upper bounds for the first- kind Bessel function $J_\nu(x)$ given recently by (for example) Lommel's, Minakshisundaram and Szász, Landau, Olenko and Krasikov, sharp bounding inequalities are obtained for the generalized Voigt function $\Omega_{\mu,\alpha,\beta,\nu}(x, y)$ in terms of the incomplete confluent Fox-Wright function ${}_1\Psi_0$.

CT-30 **Analysis of plane wave propagation under fractional order thermoelasticity**

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The present work is concerned with the propagation of harmonic plane wave propagating with assigned frequency by implementing the thermo-elasticity theory based on fractional order heat conduction law where the fractional order parameter α satisfies $(0 < \alpha \leq 1)$. After formulating the problem, the exact dispersion relation solutions for the plane wave are determined analytically and asymptotic expressions of different characterization of the wave are analyzed in two special cases, namely for high frequency field and low frequency field. Two different modes: thermal and elastic mode longitudinal waves are found. Finally we compute wave characterizations for the intermediate values of frequency and verify our analytical results for the limiting cases of wave frequency. A detailed analysis is presented to highlight the effects of fractional order parameter, α on the wave fields. Several important points are highlighted and the most important point which we have found is that in the case of thermal wave, when α goes beyond 0.5, the nature of wave changes significantly and as α gets the value nearer to 1 it behaves more similar nature with the LS model.

CT-31 **Bessel wavelet Convolution Involving Hankel Transform**

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The convolution associated with the Bessel wavelet transform is investigated and other results related to the aforesaid convolution are discussed. Boundedness of the normalized Bessel wavelet, transform on generalized Sobolev space $B^{\mu}_{p,k}(I)$ is obtained by using the theory of Hankel transform.

CT-32 **An Exact Smooth Convex Reformulation of the Quadratic Programme**

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The quadratic programme with linear equality constraints, is reformulated as an unconstrained minimization of a differentiable quadratic function. Unlike other penalty functions, the parameter involved in the unconstrained reformulation can be easily determined by the Frobenius norm of the Hessian matrix of the original objective function. Moreover it has been proved that, whenever the original quadratic programme possesses a solution, the reformulated objective function is convex.

Turán type inequalities for some special functions

CT-33

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We present some Turán type inequalities for Struve functions of the first kind by using various methods developed in the case of Bessel functions of the first and second kinds. We obtain new formulas, such as Mittag-Leffler expansion and infinite product representation for Struve functions of the first kind, which may be of independent interest. Moreover, we derive some Turán type inequalities for the general Bessel function, monotonicity and bounds for its logarithmic derivative. We also find the series representation and the relative extrema of the Turánian of general Bessel functions.

Weighted pseudo Almost periodic solutions for two-term time fractional impulsive differential equations

CT-34

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In this paper, we are interested to establish the existence and uniqueness of the piecewise weighted pseudo almost periodic mild solutions for the following two-term time fractional impulsive differential equations

$$\begin{gathered} {}^{c}D^{\mu+1}y(t) + \beta {}^{c}D^{\nu}y(t) = Ay(t) + {}^{c}D^{\mu}f(t, y(t)), \quad t > 0, t \neq t_i, \\ \Delta y(t_i) = y(t_i^+) - y(t_i^-) = I_i(y(t_i)), \quad i \in \mathbb{Z}^+, \\ y(0) = y'(0) = 0. \end{gathered}$$

where $0 < \mu \leq \nu \leq 1, \beta > 0$, ${}^{c}D^{\alpha}$ denotes the Caputo fractional derivative of order $\alpha > 0$. f and I_i are appropriate functions which satisfy some suitable conditions. $y(t_i^-)$ and $y(t_i^+)$ represent the left and right limits of $y(\cdot)$ at t_i, $i \in \mathbb{Z}^+$, respectively. The results are obtained by using Banach and Schaefer's fixed point theorems for Lipschitz and non-Lipschitz forcing terms in a Banach space. At last, an example is provided to show the feasibility of the theory discussed in this paper.

CT-35

An extension of Vietoris' inequalities for positivity of trigonometric polynomials

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In this work, a generalization of renowned Vietoris' theorem for the positivity of cosine and sine sums is provided. Conditions on specific type of the coefficient $\{a_k\}$ are found such that the corresponding sine sum $\sum_{k=1}^{n} a_k \sin k\theta$ and cosine sum $a_0 + \sum_{k=1}^{n} a_k \cos k\theta$ are positive in the unit disc $\mathbb{D}$. This idea is extended to find the monotonicity property of cosine sums as well. Among several applications possible, the starlikeness of the Gaussian Hypergeometric function is outlined.

CT-36

Estimates for Coefficients of certain Analytic Functions

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For $-1 \leq B \leq 1$ and $A > B$, we consider the class of Janowski starlike functions consisting of all normalized analytic functions f defined by the subordination $zf'(z)/f(z) \prec (1 + Az)/(1 + Bz)(|z| < 1)$. For functions in this class and its meromorphic counterpart, we investigate the inverse coefficient problem. Also, for $-1 \leq B \leq 1 < A$, the sharp bounds for first five coefficients for inverse functions of Janowski convex functions are determined. A simple and precise proof for inverse coefficient estimations for Janowski convex functions is provided for the case $A = 2\beta - 1(\beta > 1)$ and $B = 1$. As an application, for $F := f^{-1}, A = 2\beta - 1(\beta > 1)$ and $B = 1$, the sharp coefficient bounds of F/F' are obtained when f is a Janowski starlike or Janowski convex function. Further, we provide the sharp coefficient estimates for inverse functions of normalized analytic functions f satisfying $f'(z) \prec (1 + z)/(1 + Bz)(|z| < 1, -1 \leq B < 1)$ and coefficient estimates for functions in the meromorphic counterpart of Janowski starlike class.

(This is a joint work with V. Ravichandran.)

Galerkin method for fractional integro-differential equations with weakly singular kernel

CT-37

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The purpose of this paper is to present an approximate method for solving the fractional integro-differential equations (FIDEs) with weakly singular kernel. The approximate method is based on the Galerkin method for solving Volterra integral equations. FIDEs can be considered as Volterra integral equation of second type. Galerkin method with a simple addition is applied to get the approximate solution of FIDEs. The convergence analysis of the presented method is also established. Jacobi polynomial is considered as basis function to get the numerical solution of the FIDEs. Illustrative examples with different solutions are considered to show the validity and applicability of the proposed method. Numerical results show that the proposed method works well and achieve good accuracy even for less number of polynomials.

Quasi-continuity on Product Spaces

CT-38

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In this present paper, the notion of Quasi-continuity on product space is introduced. The set of all such Quasi-continuous and bounded functions defined on a closed and bounded interval is established to be a commutative Banach algebra under supremum norm.

Convolution properties of a Harmonic function with n-Starlike mappings and its partial sums

CT-39

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In 1981, Sãlãgean defined the n-starlike functions. In this paper, we check the univalency and the convexity in the direction $\alpha(0 \leq \alpha < 2\pi)$ of the convolution $\phi \tilde{*} f = \phi * h + \overline{\phi * g}$, of some harmonic functions $f = h + \bar{g}$ with n-starlike function ϕ. Also, we prove all the partial sums of the product $\phi \tilde{*} K = \phi * H + \overline{\phi * G}$ and $\phi \tilde{*} L = \phi * M + \overline{\phi * N}$ are univalent and convex in the direction of real-axis, where ϕ is 6-starlike, $k = H + \overline{G}$ is harmonic Koebe function and $L = M + \overline{N}$ is harmonic half-plane mapping introduced by Clunie and Sheil-Small in 1984.

(This is joint work with V. Ravichandran)

CT-40

Generalized vector valued paranormed sequence space using Orlicz function

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In this paper, we introduced a vector valued paranormed space $X(E, \Delta^m, M, p, s)$ using Orlicz function M. Class of vector valued sequences $X(E, \Delta^m, M, p, s)$ is defined as

$$X(E, \Delta^m, M, p, s) = \left\{ x \in W(E) : \left(|\nu_k|^{-s} \left[M\left(\frac{q(\Delta^m x_k)}{\rho} \right) \right]^{p_k} \right) \in X \right. \\ \left. \text{for some } \rho > 0, s \geq 0 \right\},$$

where (E, q) is a seminormed space, $p = (p_k)$ is a bounded sequence of positive real numbers such that $\inf_k p_k > 0$,

$$\Delta^m x_k = \sum_{i=0}^{m} (-1)^i \begin{pmatrix} m \\ i \end{pmatrix} x_{k+i}, \ m \in \mathbb{N}_0 = \{0, 1, 2, 3, \cdots\},$$

$W(E) = \{x = (x_k) : x_k \in E\}$ is a linear space under operations of vector addition and scalar multiplication, and $\nu = (\nu_k)$ be a bounded sequence of real or complex numbers such that $\inf_k |\nu_k| > 0$. Further, let X be a normal sequence algebra with absolutely monotone norm $\| \cdot \|_X$ and having a Schauder basis (e_k), where $e_k = (0, 0, \cdots, 0, 1, 0, \cdots)$ with 1 in k^{th} place. The topology on $X(E, \Delta^m, M, p, s)$ is introduced with the help of paranorm g, which is given by

$$g(x) = \sum_{i=1}^{m} q(x_i) + \inf \left\{ \rho^{(p_n/H)} : \left\| \left(|\nu_k|^{-s} \left[M\left(\frac{q\left(\Delta^m x_k\right)}{\rho} \right) \right]^{p_k} \right) \right\|_X^{1/H} \leq 1, \ n \in \mathbb{N} \right\},$$

where $x \in X(E, \Delta^m, M, p, s)$ and $H = \max(1, \sup_k p_k)$. Completeness, normality, inclusion relations etc. for this space is obtained. The results of this paper includes, as particular case, some of the known scalar and vector valued sequence spaces.

CT-41

Subordination Properties for Starlike Exponential functions

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Let p be an analytic function defined in the unit disk $\mathbb{D} = \{z : |z| < 1\}$ with $p(0) = 1$. In this note, we determine the condition on β so that $p(z)$ is subordinated to exponential function when $p(z) + \beta z p'(z)/p^j(z)$, (j=0,1,2) is subordinated to $\sqrt{1+z}$. In addition, these results are applied to obtain sufficient conditions for normalized analytic functions f belong to certain subclasses of starlike functions.

(This is joint work with Prof. V. Ravichandran)

On Wavelet Induced Isomorphisms for Reducing Subspaces

CT-42

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In this paper, we adapt the notion of a wavelet induced isomorphism of $[0,1)$ associated with a wavelet set, introduced by E.J.Ionascu in the paper [1] to the case of an $\mathcal{H}$ wavelet set, where $\mathcal{H}$ is a reducing subspace of $L^2(\mathbb{R})$. We characterize all these wavelet induced isomorphisms and provide specific examples of this theory in the case of symmetric $\mathcal{H}$- wavelet sets.

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Common Fixed Point Theorems for two Selfmaps in a Complete D^*- metric spaces

CT-43

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The purpose of this paper is to prove a common fixed point theorem for two selfmaps and a common fixed point theorem for two selfmaps in a complete D^*-metric space. Also we show that a common fixed point theorem for two selfmaps in a metric space provided by Das and Naik [1] follows as a particular case of our result.

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Level sets of (P,Q) outer generalized Pseudo Spectrum

CT-44

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Let X be complex Banach space. Given $T,P,Q \in B(X)$ with P and Q are idempotent operators, if there exists an operator S such that

$$STS = S, \quad ST = P, \quad , I - TS = Q$$

then we say that T is (P,Q) outer generalized invertible and S is (P,Q) outer generalized inverse of T, denoted by $T^{(2)}_{P,Q}$. Globevnik [1] proved that, for $\epsilon > 0$, the level set $\{\lambda \in \rho(T) : ||(T-\lambda I)^{-1}|| = \epsilon\}$, corresponding to ϵ, has empty interior in the unbounded component of $\rho(T)$. Using this result, Shrgorodsky in [2], discussed about intricacies of the definition of pseudo spectrum. We extend Globevnik result as follows: for $\epsilon > 0$, a compact operator T and a nonzero, non compact, idempotent operator P which is commuting with the operators $(T-\lambda.I)^{-1}$ for $\lambda \in \rho(T)$, the level set of $(P, I-P)-\epsilon$ pseudo spectrum $\left\{\lambda \in \mathbb{C} : \left|\left|(T-\lambda I)^{(2)}_{P,I-P}\right|\right| = \epsilon\right\}$ has empty interior.

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CT-45 Bounds for the second Hankel Determinant and the Fekete-Szegö Coefficient Functional of Certain Analytic Functions

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Let φ be an analytic function with the positive real part, $\varphi(0) = 1$ and $\varphi'(0) > 0$. Let $f(z) = z+a_2z^2+a_3z^3+\cdots$ be an analytic function satisfying the subordination $\alpha f'(z)+(1-\alpha)zf'(z)/f(z) \prec \varphi(z)$, $(f'(z))^{\alpha}(zf'(z)/f(z))^{(1-\alpha)} \prec \varphi(z)$, $(f'(z))^{\alpha}(1+zf''(z)/f'(z))^{(1-\alpha)} \prec \varphi(z)$, $(f(z)/z)^{\alpha}(zf'(z)/f(z))^{(1-\alpha)} \prec \varphi(z)$ or $(f(z)/z)^{\alpha}(1+zf''(z)/f'(z))^{(1-\alpha)} \prec \varphi(z)$. For these functions, the bounds for the second Hankel determinant $a_2a_4 - a_3^2$ as well as the Fekete-Szegö coefficient functional are obtained. Our results include some previously known results.

(This is a joint work with Dr. V. Ravichandran and Dr. S. Sivaprasad Kumar)

CT-46 Common fixed Point Theorem for $\alpha - \mathcal{Z}-$ contraction and Applications to ODE and Dynamic Programming

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In this paper, we introduce notion of $\alpha - \mathcal{Z}-$ contraction condition in metric-like space and derive based fixed points results for generalized $\alpha-$admissible pair in the underlying space. We also derive some consequences from our obtained results. Useful examples are illustrated to justify the applicability and effectiveness of results presented herein. As applications, the existence of solution of fourth- order two-point boundary value problems and existence of common solution for system of functional equations arising in dynamic programming have been studied.

Quasi-orthogonality of some Basic Hypergeometric Polynomials

CT-47

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The notion of quasi-orthogonal polynomials which is introduced and studied by Riesz[10], latter by Chihara[2] play a significant role in the area such as interpolation theory, electrostatics, rational approximations etc. Recent contribution on this direction may be found from the works due to Brezinski et.al.[1], Joulak[9], Johnston and Jordaan[7] and Johnston et.al.[8]. The question is whether similar techniques can be used to study the properties of the zeros of basic hypergeometric polynomials. Not much known about the quasi-orthogonality and real zeros of basic hypergeometric polynomials. In [6], Gochhayat et.al. studied the interlacing properties and bounds for the zeros of ${}_2\phi_1$ hypergeometric polynomials and the little $q-$Jacobi polynomials. In the present paper, we use a consequence of generalized version of results by Johnston and Jordaan[7] and give new information about the zeros of some ${}_2\phi_2$ and ${}_3\phi_2$ quasi-orthogonal polynomials.

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Certain $q-$Series Identities and Applications to Lecture Hall Type Partitions

CT-48

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In this work, using the contiguous relations for basic hypergeometric series q summation formula and some recurrence relations for $q-$Jacobi polynomials are found. Some of these results are new and the proof of remaining are shorter than the one exist in the literature. Usage of one of these results in verifying Lecture Hall type partitions is also exhibited.

On the degree of approximation of functions in a weighted Lipschitz class by almost matrix means of their fourier series

CT-49

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In this paper, we obtain the degree of approximation of functions belonging to the weighted Lipschitz class $W(L^p, \xi(t))$ and their conjugate through almost matrix means of their Fourier series and conjugate Fourier series, respectively. We also derive some corollaries from our theorems.

Approximation of $\tilde{f}$, conjugate function of f belonging to a subclass of L^p-space, by product means of conjugate Fourier series

CT-50

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The deviation of $\tilde{f}$, conjugate function of f, by various summability means of its conjugate Fourier series has been of growing interest of researchers. Recently, the authors [1] has estimated the pointwise deviation of $\tilde{f}$ in terms of modulus of continuity in L^p-space by product means. In this paper, we obtained the deviation of $\tilde{f}$, conjugate function of f belonging to a subclass of $L^p(p \geq 1)$-space, with less assumption conditions on the product matrix. We introduce different conditions on the modulus of continuity. We also discuss the case for $p = 1$ separately. Our results are free from p.

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On some coefficient Bounds associated with k-th root transformation using Quasi- Subordination

CT-51

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Quasi subordination is an essential concept in the area of complex function theory. It is an remarkable topic which collaborate the concept of both subordination and majorization. Exploiting this article, we estimate the Fekete-Szegö Functional with k-th root transform for certain classes of analytic univalent functions using quasi subordination. The authors sincerely hope this article will refresh this concept and persuade the other young researchers to work in this quasi subordination in the near future in the area of complex function theory.

Transformation of LQR Problem for Descriptor System to LQR problem for State Space System

CT-52

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The paper studies the following linear quadratic regulator (LQR) problem

$$\text{Minimize } J(x,u) = \int_0^\infty (x^T Q x + u^T R u) dt, \tag{1}$$

subject to

$$E\dot{x}(t) = Ax(t) + Bu(t), \tag{2}$$

where $E, A \in \mathbb{R}^{n\times n}, B \in \mathbb{R}^{n\times r}$ are arbitrary constant matrices, and rank $E = n_0 \leq n$. The vector $x(t) \in \mathbb{R}^n$ is called the state and $u(t) \in \mathbb{R}^r$ is called the control (input) vector of the system. Moreover, the weighting matrices Q and R are real symmetric positive semi definite and positive definite respectively. Clearly, the state space system given by

$$\dot{x}(t) = Ax(t) + Bu(t), \tag{3}$$

where $A \in \mathbb{R}^{n\times n}$ and $B \in \mathbb{R}^{n\times r}$ is a particular case of system (2). In modeling of a real world problem, the employment of various physical laws naturally yields systems of the form (2). So, in this work we have transformed the LQR problem for descriptor system (2) into the LQR problem for state space system (3). The approach is totally algebraic and based on the matrix theory. The optimal control is synthesized as state feedback. An example is provided to illustrate the effectiveness of the presented theory.

CT-53

On the Distribution of Non-Zero Zeros of Generalized Mittag-Leffler Functions

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In this work, we derive some theorems involving distribution of non-zero zeros of generalized Mittag-Leffler functions of one and two variables.

CT-54

Two Fixed Point Theorems for Non-Expansive Mappings

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In the present paper two unique common fixed point theorems for non-expansive mapping which in pair satisfy weakly compatible condition. An attempt has been made to prove the first result for weaker Suzuki type (C) condition and the second outcome is proved on convex metric space. Both the results generalize many results available in the literature.

CT-55

On Algebraic Properties of Horizontally Quasi-continuous Functions

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In this paper, we examine some algebraic properties of real valued horizontally quasi-continuous functions. The notions of upper and lower horizontally quasi-continuous functions are introduced. Examples are provided wherever necessary.

Trajectory controllability of fractional-order $\alpha \in (1, 2]$ integro-differential system with nonlocal condition

CT-56

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In this paper, we consider the following nonlinear fractional-order integro-differential system

$$^{C}D_t^{\alpha} y(t) \quad = \quad Ay(t) + B(t, u(t)) + F\left(t, y(t), \int_0^t G(t, s, y(s))\mathrm{d}s\right), \; t \in [0, \tau], \tag{4}$$

with nonlocal initial conditions $y(0) + h(y) = y_0$ and $y'(0) = y_1$, where the state $y(t)$ and the control $u(t)$ take their values in the Hilbert spaces Y and U respectively, for each t. Here, the positive constant $\tau < \infty$, $^{C}D_t^{\alpha}$ is the Caputo fractional derivative for $1 < \alpha \leq 2$. The operators A, B, F, G and h are defined as follows: $A : D(A) \subset Y \to Y$ is a closed linear operator with dense domain $D(A)$ and generates a strongly continuous α-order cosine family $C_\alpha(t)$, the maps $B : [0, \tau] \times U \to Y$, $G : \Delta \times Y \to Y$, $F : [0, \tau] \times Y \times Y \to Y$ and $h : C([0, \tau]; Y) \to Y$ are nonlinear operators, where $\Delta = \{(t, s) \in [0, \tau] \times [0, \tau] : 0 \leq s \leq t \leq T\}$ and $C([0, \tau]; Y)$ represents the space of all continuous functions. We study the trajectory controllability of ((4)) in the finite and infinite dimensional spaces with the suitable assumptions. Finally, some examples will be given to illustrate the proposed theory.

Existence and Concentration of Solutions for a Class of Elliptic PDE's involving p-biharmonic Operator

CT-57

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In this talk, an existence result pertaining to a nontrivial solution to the problem

$$\begin{cases} \Delta_p^2 u - \Delta_p u + \lambda V(x)|u|^{p-2}u = f(x, u), x \in \mathbb{R}^N, \\ u \in W^{2,p}(\mathbb{R}^N), \end{cases}$$

where $\lambda > 0, p > 1, N > 2p$ and $V \in C(\mathbb{R}^N, \mathbb{R}^+), f \in C(\mathbb{R}^N \times \mathbb{R}, \mathbb{R})$ with certain properties will be presented. Further, the concentration of solutions to the problem will be discussed on the set $V^{-1}(0)$ as $\lambda \to \infty$.

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CT-58

Common Fixed point theorem in Intuitionistic Menger spaces by using implicit relation with the property CLR_{ST}

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In this present paper, we prove some common fixed point theorems for weakly compatible mappings in intuitionistic Menger space using the common property (E.A.) for four finite families of self mappings.

Spectral Theorem for Quaternionic Compact Normal Operators CT-59

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In this talk, we prove two versions of the spectral theorem for quaternionic compact normal operators, namely the series representation and the resolution of identity form. We prove the series representation by using simultaneous diagonalization. The resolution of identity version is proved by associating a complex linear operator to the given quaternionic linear operator and applying the classical result. In the process we prove some of the interesting results on spherical spectrum of compact operators and the singular value decomposition.

Extension of Prefunctions and its relation with Mittag-Leffler function CT-60

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Exponential functions, trigonometric functions and hyperbolic functions plays very important role in pure and applied mathematics. These functions are useful for handling many engineering and technological problems. Extension of these functions is very interesting area of latest developments.

This paper devotes the study of pre-trigonometric and pre-hyperbolic functions. Starting with basic definitions, these functions are further generalized. It is shown that these generalized functions are related with well known Mittag-Leffler function which plays very important role in fractional calculus. Using Laplace transform, we have shown that they are solutions of differential equations. Finally we illustrate some properties of these functions.

Equilibrium problems under generalized monotonicity in FC spaces CT-61

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In this paper, we have studied a class of mixed equilibrium problems under generalized $\alpha - \eta$ quasimonotonicity in finitely continuous topological spaces, in short FC spaces. Existence of the solution to the problem is established by relaxing the convexity structure and the linearity condition using RKKM technique. We have proposed an iterative scheme using auxiliary principle technique. Solvability of the auxiliary equilibrium problem is also established. Finally, convergence of the iterates to the exact solution is proved. The results obtained in this paper improve and generalize some results from recent literature in the framework of FC space under weaker conditions. They are also useful to solve problems where the domain and range of the underlying mappings lack the convexity structure.

Stability criteria for uncertain $2-D$ Discrete systems in presence of generalized overflow nonlinearities

CT-62

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This work considers the problem of global asymptotic stability of two-dimensional $(2-D)$ discrete systems in the presence of generalized overflow nonlinearities. The $2-D$ models considered are the well known Fornasini Marchesini Second Local state-space model and the Roesser model. The effect of uncertainties and interval-like-time-varying delay on the system is also considered in the study. Using reciprocally convex approach we provide linear matrix inequality (LMI) based stability criteria. Numerical examples are provided to illustrate the applicability of the results. Generalized overflow nonlinearities occur during the finite wordlength (or fixed-point) implementation of discrete systems. In the previous studies a delay-dependent stability criterion for $2-D$ discrete systems under the influence of generalized overflow has not been provided. This work finds significance in the light that the models considered for the purpose of study are useful for representing a wide range of practical systems such as heat diffusion, thermal processes, river pollution modeling, image data processing, seismographic data processing, wireless sensor networks, iterative learning control, etc.

Non-linear stability of Triangular libration points in elliptic restricted three body problem with radiating and triaxial primaries

CT-63

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The non-linear stability analysis of the elliptic restricted three body problem has been considered. The model consists of three bodies, called primaries. These primaries move orbit around each other taking elliptic path. The massive of the three primaries is a radiating one, the less massive one is triaxial. The third body has negligible mass as compared to the two primaries. This body does not effect the two primaries but is affected by both. The system has solutions called the equilibrium solutions. There are five equilibrium points. The three equilibrium points lie on a straight line configuration with the primaries, hence are called collinear points. Two of them form triangular configuration with the primaries and so are called Triangular equilibrium points. The stability of the triangular libration points under the presence and absence of resonances of third order. For the stability analysis of the non-resonance case KAM theorem has been used. The Hamiltonian of the problem has been expanded in small neighborhood of the triangular libration points correct to fourth order of terms. The normalization of the Hamiltonian has been done by Birkhoff's method. The equilibrium position is found to be unstable for small values of e (eccentricity) for all resonance cases of third order using Markeev's theorem. This work is significant as resonances are often cause perturbations in the system. So this study can help us to explore resonances and their nature in similar type of models.

Weak solutions to generalized stochastic Burgers' equation perturbed by a space-time white noise

CT-64

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The existence of the weak solutions is shown for the one-dimensional generalized stochastic Burgers' equation having polynomial nonlinearity on $[0, 1]$ forced by space-time white noise with non-Lipschitz coefficient term and Dirichlet boundary conditions.The existence of the solution is obtained by an appropriate approximation procedure.

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Certain Subclasses of Bi-Univalent functions Associated with Salagean Operator

CT-65

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The purpose of the present paper is to introduce new subclasses of the class of bi-univalent functions by using Salagean operator. Furthermore, we obtain estimates on the coefficients $|a_2|$ and $|a_3|$ for functions of these subclasses. Relevant connections of well-known results are briefly indicated.

CT-66

Convolutions in time dependent heat conduction equations

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Weighted norm inequalities for convolutions are employed to analyze solutions of general heat conduction equations. The stability behavior of these equations will be talked about in connection with the hypergeometric form of Hermite interpolating polynomials. Various special cases will be considered.

CT-67

Robin Boundary value problems for a singularly Perturbed weakly coupled system of Convection-Diffusion equations having discontinuous source term

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In this paper, we consider a weakly coupled system of convection-diffusion equations subject to Robin type boundary value problems having boundary and interior layers. The diffusion term of each equation is multiplied by small singular perturbation parameters which are assumed to be different in magnitude. A central difference approximation has been used to obtain the difference scheme for the given problem in conjunction with piecewise uniform Shishkin mesh. Presence of small perturbation parameters and discontinuity in the source term leads to overlapping and interacting boundary and interior layers. It is proved that the numerical approximation produced by this method is almost first order uniformly convergent with respect to both small parameters. Numerical results are presented which validate the theoretical results.

CT-68

Solutions to abstract Volterra Integro-Differential equation with repeated deviating arguments

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We study the existence and uniqueness of solutions for a non-autonomous Volterra integro-differential equation of parabolic type with repeated deviating arguments in an arbitrary Banach space. The existence of a solution is established in a Banach space with smooth source terms in a Banach space. While the existence and uniqueness of a solution are proved in a Hilbert space without smoothness conditions. The continuation of a solution is also discussed of the problem. As an application, we illustrate the theory by an example.

Iterative roots of Continuous functions with Non-isolated Forts

CT-69

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Iterative root problem is one of the classical problems in analysis and is described as follows: Given a self-map F and a positive integer n, find a self-map f such that $f^n = F$, where f^n denotes the $n-$fold composition of f with itself. This problem is solved only for a class of piecewise monotone continuous functions on a compact interval. In this paper, we present results on the existence of iterative roots of continuous functions depending on the number of non-isolated forts.

Hyers-Ulam Stability of a Semiclosed Operator

CT-70

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In a Hilbert space $\mathcal{H}$, an operator T is semiclosed provided that there exists a bounded operator B on $\mathcal{H}$, with range the domain of T, such that TB is bounded. This is the smallest class of operators contains all closed operators and closed under sum and product. We discuss the Hyers-Ulam stability of an operator in this class.

Convolution properties of some harmonic mappings in the right half-plane

CT-71

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It is well known that harmonic convolution of two normalized right half-plane mappings is convex in the direction of the real axis provided that the convolution is locally univalent and sense-preserving in $E = \{z : |z| < 1\}$. Further, it is also known that the condition, the convolution is locally univalent and sense-preserving in E, can be dropped when one of the convoluting functions is the standard right half-plane mapping with dilatation $-z$ and other is the right half-plane mapping with dilatation $e^{i\theta}z^n$, $n = 1, 2$, $\theta \in R$. It is also known that this result does not hold for $n = 3, 4, 5, \ldots$. In this paper, we generalize this result by taking the dilatation of one of the right half-plane mappings as $e^{i\theta}z^n$ ($n \in N, \theta \in R$) and that of the other as $(a - z)/(1 - az)$, $a \in (-1, 1)$. We shall prove that our result holds true for all $n \in N$, provided the real constant a is restricted in the interval $[(n - 2)/(n + 2), 1)$. The range of the real constant a is shown to be sharp.

CT-72

Partial sums of Wright function

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In the present investigation, Wright function with their normalization are considered. In this paper, we will study the ratio of a normalized Wright function to its sequence of partial sums $(\mathcal{W}_{\lambda,\mu})_n(z) = z + \sum_{k=1}^{n} \frac{\Gamma(\mu)}{k!\Gamma(\lambda k+\mu)} z^{k+1}$. We will determine lower bounds for $\Re\left\{\frac{\mathcal{W}_{\lambda,\mu}(z)}{(\mathcal{W}_{\lambda,\mu})_n(z)}\right\}$, $\Re\left\{\frac{(\mathcal{W}_{\lambda,\mu})_n(z)}{\mathcal{W}_{\lambda,\mu}(z)}\right\}$, $\Re\left\{\frac{\mathcal{W}'_{\lambda,\mu}(z)}{(\mathcal{W}'_{\lambda,\mu})_n(z)}\right\}$ and $\Re\left\{\frac{(\mathcal{W}'_{\lambda,\mu})_n(z)}{\mathcal{W}'_{\lambda,\mu}(z)}\right\}$. Results obtained are new and their usefulness are depicted by deducing several interesting examples.

CT-73

Trajectory Controllability of Fractional differential Systems of Order $\alpha \in (1, 2]$ with Deviated Argument

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In this paper, we consider a control system governed by the fractional differential equation of order $\alpha \in (1, 2]$ with deviated argument in a Banach space X. We used the strongly continuous α-order cosine family of linear operators and Gronwall's inequality to study the trajectory controllability of the system. Also, we study the trajectory controllability of the integro-differential equations. Finally, we give an example to illustrate the application of these abstract results.

CT-74

The existence of instantaneous gelation to the nonlinear continuous Smoluchowski coagulation equation

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Coagulation is a kinetic process in which two particles combine together to form a bigger particle at a particular instant or time. This process has many applications in different branches of science, engineering and technology. In this work, we are mainly interested in coagulation process, which is governed by an integro-partial differential equation. This is also known as Smoluchowski coagulation equation (SCE). We know that the total mass of the system is conserved during the coagulation process. Therefore it is expected that the total volume (mass) remains constant throughout the time. However for some coagulation kernels, the total mass of the system breaks down after a finite time, this phenomenon is known as *gelation*. Moreover, if the gelation occurs at time $t_g = 0$, then it is called *instantaneous gelation*.

In the present work, we discuss the existence of the instantaneous gelation (in weak sense) on a weighted L^1 space to the general continuous SCE for large classes of unbounded coagulation kernels. The proof is based on the assumption that the mass conservation property of the solution holds for a finite time interval which leads to the finiteness of higher moments. However, a contradiction is obtained by observing the blow up of higher moments within an infinitesimal time interval.

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A discontinuous finite volume approximation for the optimal control of the Brinkman equations

CT-75

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In this paper we discuss a discontinuous finite volume discretization for the distributed optimal control problem governed by the Brinkman equations written in terms of velocity and pressure. A priori error estimates are developed for different types of control discretizations (piecewise linear, piecewise constant and variational discretization) in suitable norms. Finally, we provide a set of numerical examples illustrating the performance of the method and confirming the predicted accuracy of the state, co-state and control approximations under various scenarios.

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