PROGRAM & ABSTRACTS

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ATMA2021 - Program at a glance

	Wednesday, Nov 10	*Thursday, Nov 11*	*Friday, Nov 12*
8:10-8:40	*Registration*		
8:40-8:50			**UMI-T.A.A. Meeting**
8:50-9:00	*Workshop opening*		
9:00-9:50	**Elisabeth Larsson**	**Ulrich Reif**	
9:50-10:10	Francesco Marchetti	Sergio López-Ureña	Martina Maiuriello
10:10-10:30	Alessia Perticarini	Lucia Romani	Marco Seracini
10:30-11:00	***Coffee break***		
11:00-11:20	Markus Weimar	Alberto Viscardi	Maryam Mohammadi
11:20-11:40	Janina Hübner	Mohammad Karimnejad E.	Giovanni Pagano
11:40-12:00	Maria Carmela De Bonis	Gianluca Vinti	Gabriele Santin
12:00-12:20	Martina Bulai	Laura Angeloni	Danilo Costarelli
12:20-12:40	Chiara Fuda	Mariarosaria Natale	*Closing remarks* & ***Lunch (offered)***
14:30-15:20	**Vladimir Protasov**	**Frank Filbir**	
15:20-15:40	Giuseppe Giordano	Emile Parolin	
15:40:16:00	Najoua Siar	Thomas Mejstrik	
16:00-16:20	Emiliano Cirillo	***Coffee break***	
16:20-16:40	Dmitry Batenkov		
16:40-17:00	Caroline Moosmüller	Giuseppe Floridia	
17:00-17:20	Sônia Gomes	Woula Themistoclakis	
17:20-17:40	**POSTER SESSION** ***(& aperitif)***	Arianna Travaglini	
17:40-18:50		**RITA Meeting**	
20:15		*Social dinner*	

POSTER SESSION
Maria Rosaria Capobianco, Roberto Cavoretto, Tiziana Ciano, Filomena Di Tommaso, Mariangela Gangemi, Attilio Marcianò, Domenica Stefania Merenda, Domenico Mezzanotte, Federico Nudo

DAY-BY-DAY PROGRAM

Wednesday, November 10	
08:10–08:50	*Registration*
08:50–09:00	*Workshop opening*
09:00–09:50	**Elisabeth Larsson**: *Simulating the human respiratory system from an approximation perspective*
09:50–10:10	Francesco Marchetti: *From the extended Rippa's scheme to the Efficient Reduced Basis Algorithm (ERBA)*
10:10–10:30	Alessia Perticarini: *A decomposition technique of a RBFs interpolation matrix in* $\mathbb{R}^2$
10:30–11:00	**Coffee break**
11:00–11:20	Markus Weimar: *Adaptive BEM and Besov-type spaces based on wavelet expansions*
11:20–11:40	Janina Hübner: *Tree approximation in Besov- and Triebel-Lizorkin-type spaces based on wavelet expansions*
11:40–12:00	Maria Carmela De Bonis: *On the solution of Prandtl type equations by a Filtered interpolation method*
12:00–12:20	Iulia Martina Bulai: *Graph signal processing and wavelet packets*
12:20–12:40	Chiara Fuda: *On the numerical stability of barycentric rational interpolation*
12:40–14:30	**Lunch time**
14:30–15:20	**Vladimir Yu. Protasov**: *Multivariate splines and subdivisions constructed by space tilings*
15:20–15:40	Giuseppe Giordano: *On the numerical time-discretization of stochastic Hamiltonian problem*
15:40–16:00	Najoua Siar: *Numerical solution of Poisson equation with Dirichlet boundary conditions through multinode Shepard operators*
16:00–16:20	Emiliano Cirillo: *A novel region extraction algorithm with applications to B-splines quasi-interpolants*
16:20–16:40	Dmitry Batenkov: *Spectral properties of Vandermonde matrices with clustered nodes and the limits of sparse super-resolution*
16:40–17:00	Caroline Moosmüller: *A factorization framework for Hermite subdivision schemes reproducing polynomials of high degree*
17:00–17:20	Sônia M. Gomes: *Composite Duffy's Approximations on Scaled Polytopes for an Operator Adapted Method*
17:20–18:50	**Poster Session (& aperitif)**

Thursday, November 11	
09:00–09:50	**Ulrich Reif**: *Geometric Hermite Subdivision*
09:50–10:10	Sergio López-Ureña: *A non-oscillatory butterfly subdivision scheme*
10:10–10:30	Lucia Romani: *Class A matrices with a real spectrum and associated planar special Bézier curves*
10:30–11:00	**Coffee break**
11:00–11:20	Alberto Viscardi: *Order 4 and 6 Exponential-Polynomial PH Curves*
11:20–11:40	Mohammad Karimnejad Esfahani: *On the Stencil Selection for Moving Least Square Method*
11:40–12:00	Gianluca Vinti: *A mathematical model for the reconstruction of digital images: a brief overview of the results of the Perugia research group*
12:00–12:20	Laura Angeloni: *Estimates in variation for multidimensional sampling-type operators and applications*
12:20–12:40	Mariarosaria Natale: *On some quantitative estimates for nonlinear multivariate sampling Kantorovich operators*
12:40–14:30	**Lunch time**
14:30–15:20	**Frank Filbir**: *Shift Invariant Spaces related to the Special Affine Fourier Transform*
15:20–15:40	Emile Parolin: *Stable approximation of Helmholtz equation solutions by evanescent plane waves*
15:40–16:00	Thomas Mejstrik: *Elliptic polytopes and invariant norms of linear operators*
16:00–16:40	**Coffee break**
16:40–17:00	Giuseppe Floridia: *Approximate controllability for nonlinear reaction-diffusion equations*
17:00–17:20	Woula Themistoclakis: *Image resizing by Lagrange and de la Vallée Poussin type interpolation*
17:20–17:40	Arianna Travaglini: *Sampling Kantorovich operators for the detection of brain pathologies*
12:40–14:30	**RITA Meeting**
20:30	**Social Dinner**

Friday, November 12	
08:40–09:50	**UMI T.A.A. Meeting**
09:50–10:10	MARTINA MAIURIELLO: *Dynamics of Shift-like Operators on L^p-spaces*
10:10–10:30	MARCO SERACINI: *Sampling type Operators for retinal characterization*
10:30–11:00	**Coffee break**
11:00–11:20	MARYAM MOHAMMADI: *A shape preserving quasi-interpolation operator based on a new transcendental RBF*
11:20–11:40	GIOVANNI PAGANO: *Explicit peer methods with jacobian-dependent coefficients*
11:40–12:00	GABRIELE SANTIN: *Kernel methods for center manifold approximation*
12:00–12:20	DANILO COSTARELLI: *Approximation properties of the sampling Kantorovich operators: regularization, saturation, inverse results and Favard classes in L^p-spaces*
12:20–14:30	Closing remarks & **Lunch (offered)**

PLENARY LECTURES

Shift Invariant Spaces related to the Special Affine Fourier Transform

Frank Filbir (Helmholtz Center Munich & Technische Universität München)

We introduce a generalized translation T_x^A associated with the special affine Fourier transform (SAFT) $\mathscr{F}_A$ and establish a generalized convolution theorem. This is being used to obtain a generalization of Wendel's theorem for SAFT multipliers. The shift invariant space $V_A(\phi)$ associated with the SAFT is introduced and characterization theorems for the system of translates T_x^A to be an orthonormal system and a Riesz sequence are obtained. In the final part of the paper sampling in the shift invariant spaces V_A is discussed along with illustrations.

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Simulating the human respiratory system from an approximation perspective

Elisabeth Larsson (Uppsala University)

When intensive care patients are put in a ventilator, both the lungs and the diaphragm, which is the main respiratory muscle, are damaged by the mechanical ventilation. This prolongs the intensive care period and is an undesired side effect. To understand these effects better, we want to simulate both natural and mechanical ventilation. This is a hard problem and here we describe the steps that we have made so far. We have chosen to use radial basis function (RBF) methods to build our model. The reason is that the methods are flexible with respect to geometry, they can be computationally efficient due to the potential high-order accuracy, and they are easy to use also for complex problems. We discuss two aspects, first building a smooth geometry from medical image data, and then RBF simulation methods that are adapted to thin geometries. We present theoretical convergence results and numerical experiments that confirm the theoretical findings.

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Multivariate splines and subdivisions constructed by space tilings

Vladimir Yu. Protasov (University of L'Aquila)

It is well-known that the multivariate wavelets on $\mathbf{R}^d$ can be constructed with an arbitrary dilation integer expansive $d \times d$ matrix and arbitrary set of "digits" from the corresponding quotient sets. The unit segment in that numerical systems becomes a tile, which is a compact set with certain self-similarity properties. As in the univariate case, the tile B-splines are defined as convolutions of tiles. In spite of a complicated structure those functions possess very good approximation properties. Moreover, some of them have higher smoothness than the usual multivariate B-splines. We analyse the corresponding wavelets and present subdivision schemes based on the tile B-splines. Surprisingly, they have a faster convergence and higher regularity than many of known subdivision schemes of the same complexity. Computing the regularity is realized by the recent formula for the Hölder exponent of multivariate refinable function constructed with an arbitrary dilation matrix: M.Charina, V.Yu.Protasov, *Regularity of anisotropic refinable functions, ACHA (2019), 795–821*. To classify all tile splines of a given number of variables we apply the notion of boundary dimension of a compact set. We show that in $\mathbb{R}^d$ there are between d^2 and 2^d B-splines of a given order, not equivalent to each other. We classify all of them in low dimensions. In the case of anysotropic dilation matrix the classification is much simple and is realized in all dimensions. Finally, we present numerical results and formulate several open problems.

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Geometric Hermite Subdivision

Ulrich Reif (TU Darmstadt), Andreas Weinmann*

We present a family of algorithms for subdividing point-normal pairs in the plane. Refinement is based on the approximate reproduction of clothoids, which are curves with a linear curvature profile. The generated limit curves have good shape properties. They are proven to be C^1 and conjectured to be C^2, where the limit of normals equals the normal of the limit curve. Other algorithms of that kind suggested in the literature do not possess the latter property.

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CONTRIBUTED TALKS

Estimates in variation for multidimensional sampling-type operators and applications

Laura Angeloni (University of Perugia), Danilo Costarelli, Gianluca Vinti*

We will present estimates in variation for some classes of sampling-type operators in multidimensional frame. In particular, we will focus our attention on the so-called variation diminishing-type estimate, that is, a classical result in BV spaces ensuring that the variation of the operator is, essentially, not bigger than the variation of the function to which it is applied. If such estimates, in the one-dimensional frame, are usually quite easy to be proved, the multidimensional case is more delicate. We will also discuss some connections of the results to problems of Digital Image Processing.

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Spectral properties of Vandermonde matrices with clustered nodes and the limits of sparse super-resolution

Dmitry Batenkov (Tel-Aviv University, Israel)

Vandermonde matrices with irregularly spaced nodes on or near the unit circle are fundamental for the study of super-resolution of sparse measures from noisy and bandlimited data. In this talk I will survey some recent results on the spectral properties of such matrices under the geometric assumptions of nodes forming clusters of sub-Rayleigh size, and discuss the implications for applications.

References

[1] D. Batenkov, L. Demanet, G. Goldman, and Y. Yomdin, "Conditioning of Partial Nonuniform Fourier Matrices with Clustered Nodes," SIAM J. Matrix Anal. Appl., vol. 44, no. 1, pp. 199–220, Jan. 2020.

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Graph signal processing and wavelet packets

Iulia Martina Bulai (Dipartimento di Matematica, Informatica ed Economia Università degli Studi della Basilicata, ITALY), Sandra Saliani*

Nowadays graphs became of significant importance given their use to describe complex system dynamics, with important applications to real world problems, e.g. graph representation of the brain, social networks, biological networks, spreading of a disease, etc., [1-3]. In this talk we will introduce a novel graph wavelet packets construction, to our knowledge different from the ones known in literature. We get inspired by the Spectral Graph Wavelet Transform defined by Hammond et al. in [4], based on a spectral graph wavelet at scale $s > 0$, centered on vertex n, and a spectral graph scaling function, respectively. Moreover after defining the wavelet packet spaces, and the associated tree, we obtain a dictionary of frames for $\mathbb{R}^N$, with known lower and upper bounds. We will give some concrete examples on how the wavelet packets can be used for compressing, denoising and reconstruction by considering a signal, given by the fRMI (functional magnetic resonance imaging) data, on the nodes of voxel-wise brain graph $\mathcal{G}$ with 900.760 nodes (representing the brain voxels) defined in [1-2].

References

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A novel region extraction algorithm with applications to B-splines quasi-interpolants.

Emiliano Cirillo (EPFL), Pablo Antolin, Annalisa Buffa*

Region extraction is a very common task in both Computer Science and Engineering with several applications in object recognition and motion analysis, among the others. Most of the literature focuses on regions delimited by straight lines, often in the special case of intersection detection among two unstructured meshes. While classical region extraction algorithms for line drawings and mesh intersection algorithms have proved to be able to deal with many applications, the advances in Isogeometric Analysis (IGA) call for a generalization of such problem to the case in which the regions to be extracted are not bounded by straight edges but by an arbitrary number of curved segments instead.

In this talk we present a novel region extraction algorithm that allows a precise numerical integration of functions defined in different spline spaces. The presented algorithm has several interesting applications in contact problems, mortar methods and quasi-interpolation problems.

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Approximation properties of the sampling Kantorovich operators: regularization, saturation, inverse results and Favard classes in L^p-spaces

Danilo Costarelli (Department of Mathematics and Computer Science, University of Perugia), Gianluca Vinti*

In the present talk, a characterization of the Favard classes for the sampling Kantorovich operators based upon bandlimited kernels has been discussed. In order to achieve the above result, a wide preliminary study has been necessary. First, suitable high order asymptotic type theorems in L^p-setting, $1 \leq p \leq +\infty$, have been proved. Then, the regularization properties of the sampling Kantorovich operators have been investigated. Further, for the order of approximation of the sampling Kantorovich operators, quantitative estimates based on the L^p modulus of smoothness of order r have been established. As a consequence, the qualitative order of approximation is also derived assuming f in suitable Lipschitz and generalized Lipschitz classes. Finally, an inverse theorem of approximation has been stated, together with a saturation result, allowing to obtain the desired characterization.

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On the solution of Prandtl type equations by a Filtered interpolation method

Maria Carmela De Bonis (University of Basilicata), D. Occorsio, W. Themistoclakis*

This talk deals with a collocation–quadrature method based on VP filtered interpolation at Chebyshev nodes for solving the following Prandtl-type equation

$$\begin{aligned} \sigma f(y) \;&-\; \frac{1}{\pi}\int_{-1}^{1}\frac{f(x)}{(x-y)^2}\varphi(x)dx - \frac{1}{\pi}\int_{-1}^{1}\log|x-y|f(x)\varphi(x)dx \\ &+\; \frac{1}{\pi}\int_{-1}^{1}h(x,y)f(x)\varphi(x)dx = g(y), \quad y\in(-1,1), \end{aligned} \tag{1}$$

where $\varphi(x)=\sqrt{1-x^2}$, σ is a real constant, h is a smooth kernel function and the first integral has to be understood as the following derivative

$$\int_{-1}^{1}\frac{f(x)}{(x-y)^2}\varphi(x)dx = \frac{d}{dy}\int_{-1}^{1}\frac{f(x)}{x-y}\varphi(x)dx,$$

being the integral at the right–hand side a Cauchy principal value integral.

Integro Differential Equations (IDEs) of the type (1) are models for many physics and engineering problems (see [8] and the references therein). Indeed, besides the well known Prandtl's Equation which governs the circulation air flow along the contour of a plane wing profile (see e.g. [6,7]), Prandtl-type equations (1) model, for instance, the load transfer problem from thin-walled elements to massive bodies (see e.g. [9]), crack problems in fracture mechanics (see e.g. [3]), etc.

Uniform convergence and stability hold in a couple of Hölder–Zygmund spaces of locally continuous functions [5]. With respect to classical methods based on Lagrange interpolation at the same collocation nodes, the method reproduces the optimal convergence rates of the L^2 case by cutting off the *log* factor which typically arises dealing with uniform norms [1,2,4]. Such an improvement does not require a greater computational effort. In particular we propose a fast algorithm based on the solution of a simple 2-bandwidth linear system and prove that, as its dimension tends to infinity, the sequence of the condition numbers (in any natural matrix norm) tends to a finite limit.

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Approximate controllability for nonlinear reaction-diffusion equations

Giuseppe Floridia (Università Mediterranea di Reggio Calabria), D. Occorsio, W. Themistoclakis*

In this talk we present some approximate controllability results for semilinear reaction-diffusion equations governed via the coefficient of the reaction term (multiplicative control). Before, we consider uniformly parabolic problems (see [1] and [3]) and we show in [1] that an one-dimensional uniformly parabolic problem can be steered from an initial continuous state that admits a finite number of points of sign change to a target state with the same number of changes of sign in the same order. Then, we extend the results obtained in [1] to degenerate reaction-diffusion equations (see [2] and [4]) with application to some energy balance models in climatology (see, e.g., the Budyko-Sellers model).

References

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On the numerical stability of barycentric rational interpolation

Chiara Fuda (Università della Svizzera Italiana), Rosanna Campagna, Kai Hormann*

The barycentric forms of polynomial and rational interpolation have recently gained popularity, because they can be computed with simple, efficient, and numerically stable algorithms [1–3]. In this talk, we show more generally that the evaluation of any function that can be expressed as $r(x) = \sum_{i=0}^{n} a_i(x) f_i \big/ \sum_{j=0}^{m} b_j(x)$ in terms of data values f_i and some functions a_i and b_j for $i = 0, \ldots, n$ and $j = 0, \ldots, m$ with a simple algorithm that first sums up the terms in the numerator and the denominator, followed by a final division, is forward and backward stable under certain assumptions. This result includes the two barycentric forms of rational interpolation as special cases. Our analysis further reveals that the stability of the second barycentric form depends on the Lebesgue constant associated with the interpolation nodes, which typically grows with n, whereas the stability of the first barycentric form depends on a similar, but different quantity, that can be bounded in terms of the mesh ratio, regardless of n. We support our theoretical results with numerical experiments, which indicate that the first barycentric form is stable even in situations where the second barycentric form is completely unstable.

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On the numerical time-discretization of stochastic Hamiltonian problem

Giuseppe Giordano (University of Salerno), Raffaele D'Ambrosio (University of L'Aquila), Beatrice Paternoster (University of Salerno)*

In this talk we focus on the study of the numerical dynamics associated to time discretizations of stochastic Hamiltonian problems, because they are reliable models to describe several natural and real-life phenomena, when they are subject to random perturbations. Specifically, our analysis focuses on the study of stochastic Runge-Kutta methods, developed by Burrage and Burrage, obtained as a stochastic perturbation of symplectic Runge-Kutta methods. In particular, these methods exhibit an error growth with the parameter ε, describing the amplitude of the diffusive part of the problem. Through a perturbative analysis in terms of ε-expansions, we justify the motivation of this behaviour. This analysis shows the presence of spurious terms, growing in time and with the parameter ε. The theoretical results are also confirmed by selected numerical experiments.

References

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Composite Duffy's Approximations on Scaled Polytopes for an Operator Adapted Method

Sônia M. Gomes∗ (IMECC-Universidade Estadual de Campinas, Brazil), Karolinne O. Coelho, Philippe R. B. Devloo

We consider general partitions by scaled (star-shaped) polytopes S, which are in turn composed by sectors meeting in a single vertex (scaling center), and parametrized by collapsed Duffy's transformations. The approximations are formed by two components: (i) a trace finite element discretization over ∂S and (b) a radial extension into S towards the scaling center. An operator-adapted principle can be adopted to define the radial extension by the resolution of local Dirichlet problems, which is a known process in the context of Scaled Boundary Finite Element Method (SBFEM) [1]. For harmonic or elasticity problems with vanishing force terms, the SBFEM spaces are defined by imposing an energy-orthogonality constraint, the shape functions being constructed locally in S from eigenvalues and eigenfunctions of an ODE system, whose coefficients are determined by the element geometry and the piecewise polynomial trace space over ∂S. Convergence in energy norm in terms of interpolation errors of the exact solution is estimated by comparison with classic finite element or virtual harmonic approaches. Numerical verification tests in two and three dimensional regions confirm the expected convergence rates [2].

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Tree approximation in Besov- and Triebel-Lizorkin-type spaces based on wavelet expansions

Janina Hübner (Ruhr University Bochum), Markus Weimar*

The talk is concerned with a non-linear approximation method via tree approximations based on wavelet expansions. We derive the exact rate of convergence of the error of the best N-term tree approximation w.r.t. embeddings between Besov and Triebel-Lizorkin spaces in all possible combinations. Finally a comparison is drawn between the rates of convergence of the well-known unconstrained best N-term, the linear non-adaptive and the tree approximation method on open and bounded domains.

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On the Stencil Selection for Moving Least Square Method

Mohammad Karimnejad Esfahani (Department of Mathematics "Tullio Levi-Civita", University of Padova), Stefano De Marchi, Francesco Marchetti*

The meshfree Moving Least Squares (MLS) method is a powerful multivariate scattered data approximation scheme that has been extensively applied to many real world data fitting problems. For approximating a function at an arbitrary point via MLS, a common approach is to choose n nearest neighbors of the point as stencil, where $n \in \mathbb{N}$ is large enough so that a good accuracy is achieved [3]. In this work, inspired by ideas proposed in [1, 2] in the context of meshless Finite Difference method, we construct the stencil by means of the column-pivoting QR (pQR) algorithm. In this approach, for the reproduction property, the size of the stencil does not exceed the dimension of the space of multivariate polynomials of total degree $q \leq n$. We show by several numerical experiments that the accuracy provided by our approach is comparable with the classical nearest neighbors scheme.

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A non-oscillatory butterfly subdivision scheme

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Subdivision schemes are an efficient tool for the computational generation of curves and surfaces. The butterfly subdivision scheme [1] is a well-known linear interpolatory scheme for the generation of $\mathcal{C}^1$ surfaces capable of exactly reproducing third degree bivariate polynomials (when the initial data is of this kind). However, as most of the linear interpolatory schemes, it produces oscillations when the initial data has large gradients. This is a usual situation when dealing with data coming from piecewise smooth function with discontinuities.

In [2] the authors explain, in the univariate case, how to transform a linear oscillatory scheme into a non-linear non-oscillatory one. The key idea is to express the given scheme as a convex combination of other schemes based on smaller stencil and, then, replace the linear averages appearing in the convex combination by non-linear analogues.

Here, we extend the ideas of [2] to the bivariate case, in particular to triangular grids, and we design a non-linear non-oscillatory version of the butterfly subdivision scheme.

This work may have applications in data compression and in the numerical solution of PDEs such as conservation laws.

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Dynamics of Shift-like Operators on L^p-spaces

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Linear Dynamics is a branch of mathematics which lies at the intersection of Operator Theory and Dynamical Systems, and it has had a flurry of intriguing results, in particular, in the last decades. We briefly recall fundamental notions as transitivity, mixing, Devaney and Li-Yorke chaos, frequent hypercyclicity, expansivity and shadowing. They are completely characterized for a fundamental class of operators: the *weighted backward shifts*. We present a general technique which allows us to lift up these characterizations to a broader class of operators on L^p spaces, the *shift-like operators*, which appear naturally as composition operators on L^p when the underlying space is dissipative.

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From the extended Rippa's scheme to the Efficient Reduced Basis Algorithm (ERBA)

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Rippa's scheme is a well known Leave-One-Out Cross Validation (LOOCV) method for the tuning of the shape parameter in RBF interpolation. Recently in [1], such scheme has been extended to a more general setting. In this talk, we present how the extended scheme can be employed for the construction of a fast and effective *knot removal* method, which we call Efficient Reduced Basis Algorithm (ERBA) [2].

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Elliptic polytopes and invariant norms of linear operators

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We address the problem of constructing elliptic polytopes in $\mathbb{R}^d$, which are convex hulls of finitely many two-dimensional ellipses with a common center. Such sets arise in the study of spectral properties of matrices, asymptotics of long matrix products, in the Lyapunov stability, etc. The main issue in the construction is to decide whether a given ellipse is in the convex hull of others. The computational complexity of this problem is analysed by considering an equivalent optimisation problem. We show that the number of local extrema of that problem may grow exponentially in d. For $d = 2, 3$, it admits an explicit solution for an arbitrary number of ellipses; for higher dimensions, several geometric methods for approximate solutions are derived. Those methods are analysed numerically and their efficiency is demonstrated in applications.

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A shape preserving quasi-interpolation operator based on a new transcendental RBF

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In recent decades, the radial basis function (RBF) interpolation has provided an outstanding tool for scattered data approximation on multidimensional cases. The Multiquadric (MQ) RBF proposed by Hardy, is undoubtedly the most popular RBF that is used in many applications and is representative of the class of global infinitely differentiable RBFs. Although the MQ interpolation is always solvable, the resulting matrix quickly becomes ill-conditioned as the number of points increases. Researchers concentrated on a weaker form of interpolation, known as quasi-interpolation, that holds only for polynomials of some low degree. It is well-known that the univariate Multiquadric quasi-interpolation operator is constructed based on the piecewise linear interpolation by $|x|$. In this talk, we first introduce a new transcendental RBF based on the hyperbolic tangent function as an smooth approximant to $\phi(r) = r$ with higher accuracy and better convergence properties than the MQ RBF $\sqrt{r^2 + c^2}$. Then the Wu-Schaback's quasi-interpolation formula is rewritten using the proposed RBF. It preserves convexity and monotonicity. We prove that the proposed scheme converges with a rate of $O(h^2)$. So it has a higher degree of smoothness. Some numerical experiments are given in order to demonstrate the efficiency and accuracy of the method.

This is a joint work with Mohammad Heidari and Stefano De Marchi.

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A factorization framework for Hermite subdivision schemes reproducing polynomials of high degree

Caroline Moosmüller (University of California, San Diego), Tomas Sauer (Universität Passau)*

Hermite subdivision schemes are iterative refinement algorithms which produce a function and its derivatives in the limit. In this talk we are interested in Hermite subdivision schemes which reproduce polynomials of high degree. We show that this can be characterized by operator factorizations involving Taylor operators and difference factorizations of a rank one vector scheme. Explicit expressions for these operators are derived, which are based on an interplay between Stirling numbers and p-Cauchy numbers. Furthermore, we discuss how this framework can be used to prove high smoothness of the limit functions.

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On some quantitative estimates for nonlinear multivariate sampling Kantorovich operators

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In recent years, there has been a large increase in interest of the scientific community in nonlinear approximation operators. Indeed, such operators are suitable in order to describe nonlinear transformations generated by certain signals that, during their filtering process, produce new frequencies. A wide literature can be found in [4, 1, 5, 3, 2].
Herein, we present some quantitative estimates for the nonlinear sampling Kantorovich operators in the multivariate setting using the modulus of smoothness of $L^{\varphi}(\mathbb{R}^n)$. As a consequence, the qualitative order of convergence can be obtained, in case of functions belonging to suitable Lipschitz classes. Furthermore, the general frame of Orlicz spaces allows us to deduce the corresponding estimates in $L^p(\mathbb{R}^n)$-spaces, $1 \leq p < +\infty$, Zygmund spaces, exponential spaces and many others. We also establish a direct quantitative estimate in the particular case of L^p-spaces, which turns out to be sharper than that one achieved in the general case. Finally, some concrete examples of nonlinear multivariate sampling Kantorovich operators are also shown.

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Explicit peer methods with jacobian-dependent coefficients

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In this talk, explicit, parallelizable and optimally zero-stable peer methods with accuracy order $p = s$ (s is the number of stages) are considered, and the application of a technique that leads to new coefficients dependent on the jacobian of the ordinary differential equations system to solve is shown. In fact, in this way, A-stable peer methods of order two and A(θ)-stable peer methods of order three preserving their explicit structure can be obtained.

The analogies between the technique applied by us, TASE (Time–Accurate and highly–Stable Explicit) methodology [1] and non-standard finite differences [2] are discussed, and numerical tests confirming the derived theoretical properties of the analyzed peer methods are shown.

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Stable approximation of Helmholtz equation solutions by evanescent plane waves

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Solutions of the Helmholtz equation ($-\Delta u - k^2 u = 0$) on a disk are known to be well approximated by a suitable superposition of propagative plane waves $\mathbf{x} \mapsto e^{\imath k \mathbf{d} \cdot \mathbf{x}}$, with $\mathbf{d} \in \mathbb{R}^2$ and $|\mathbf{d}| = 1$. This observation is the foundation of successful Trefftz methods [3]. However, when too many plane waves are used, the computation of the expansion is known to be numerically instable. This effect is due to (exponentially) large coefficients present in the expansion and can drastically limit the efficiency of the approach.

In this work, we show that the Helmholtz solutions on a disk can be exactly represented by a continuous superposition of evanescent plane waves, which are found to form a continuous frame for the solution space, generalizing the standard Herglotz representation. Here, by evanescent plane wave, we mean a plane wave where the defining direction $\mathbf{d}$ is chosen in $\mathbb{C}^2$, resulting in an exponentially decaying modulus in one direction. In addition, the Herglotz density is proved to be uniformly controlled by the target of the approximation, hence overcoming the instability observed with propagative plane waves and paving the way for stable discrete expansions.

In view of practical implementations, discretizations strategies are investigated. We construct suitable finite dimensional sets of evanescent plane waves using optimal sampling strategies in a parametric space in the spirit of the recent work [2]. Provided one uses sufficient oversampling and regularization [1], the resulting approximations are shown to be both controllably accurate and numerically stable, as supported by numerical evidence.

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A decomposition technique of a RBFs interpolation matrix in $\mathbb{R}^2$

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When dealing with interpolation problems that require high order accuracy, radial basis functions (RBFs) are powerful tools, especially when we have a large number of interpolation nodes. Let $N_C \in \mathbb{N}$ be the number of interpolation points, solving the interpolation problem means inverting a square matrix A of order N_C. This inversion requires a computational cost that grows as N_C^3, therefore, in order to perform the matrix inversion in a reasonable time, a proper decomposition of matrix A would be favourable. A preliminary idea is to use a decomposition of the form $A = UDV$, where U is a rectangular matrix of order $N_C \times m$, D is a diagonal matrix of order m, and V is rectangular of order $m \times N_C$, where $m < N_C$. In the case of the inverse multiquadric RBFs (IMRBFs) in a domain $\Omega \subset \mathbb{R}^2$, we propose to obtain such decomposition in the following way. We observe that the IMRBF in $\mathbb{R}^2$ can be written as the Green's function of the laplacian operator in $\mathbb{R}^3$, for a particular choice of the $z-$coordinate. Then, we exploit the spectral decomposition in spherical coordinates of the Green's function, which shows separation of variables, thus it gives a decomposition for the IMRBF and, in turn, the sought decomposition for the interpolation matrix. In addition, the Green's function decomposition consists of a series whose discrete counterpart converges for points that have radius in spherical coordinates quite different from each other. Then, in the points where the truncated series loses accuracy, a translation technique based on the Rokhlin fast multipole method is applied.

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Class A matrices with a real spectrum and associated planar special Bézier curves

Lucia Romani (Alma Mater Studiorum Università di Bologna), Alberto Viscardi*

Special Bézier curves are polynomial Bézier curves whose control polygon is fully identified by the first edge and a representative matrix. In this talk we focus on 2×2 representative matrices with real eigenvalues. We formulate necessary and sufficient conditions with respect to such matrices so that every associated special Bézier curve is a class A curve, i.e., a planar curve with monotone curvature. The result fills a research gap in the literature and provides a condition for both designing planar class A curves and analyzing given special Bézier curves in the plane.

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Kernel methods for center manifold approximation

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The Center Manifold Theorem (CMT) can be used to study the stability of a dynamical system with an hyperbolic equilibrium in a reduced dimensional setting. In this talk we discuss a recent robust version of the CMT which shows that a sufficiently accurate approximation of the center manifold can be used in place of the exact one. Moreover, we present a kernel-based approximation scheme that can construct this type of approximation in a data-based fashion, using numerical samples of the system trajectories.

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Sampling type Operators for retinal characterization

Marco Seracini (University of Perugia), D. Costarelli G. Vinti*

Sampling Kantorovich operators (SKO) have been introduced in the mathematical literature to extend the results of the classic and generalized sampling theorems to class of not necessarily continuous functions.
Starting from the one dimensional case, their formalization has been extended to multidimensional asset [4].
Thanks to their low-pass characteristic [2], SKO have been successfully applied to image reconstruction for the solution of both medical as engineering specific problems [1,3].
Taking into account these results, Optical Coherence Tomography (OCT) data have been reconstructed by mean of the SKO, achieving improved images of the retinal fundus in terms of perceivable visual quality. A new hybrid segmentation procedure together with a cluster counting measurement has been introduced to quantify the quality of the final reconstructions and estimate the grade of connectivity in the retinal tissue.

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Numerical solution of Poisson equation with Dirichlet boundary conditions through multinode Shepard operators

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The multinode Shepard operator is a linear combination of local polynomial interpolants with inverse distance weighting basis functions. This operator can be rewritten as a blend of function values with cardinal basis functions, which are a combination of the inverse distance weighting basis functions with multivariate Lagrange fundamental polynomials. The key for simply computing the latter, on a unisolvent set of points, is to use a translation of the canonical polynomial basis and the $PA = LU$ factorization of the associated Vandermonde matrix [1]. In this talk, we propose a method to numerically solve a Poisson equation with Dirichlet conditions through multinode Shepard interpolants by collocation. This collocation method gives rise to a collocation matrix with many zero entrances and a smaller condition number with respect to the one of the well known Kansa method [2]. Numerical experiments show the accuracy and the performance of the proposed collocation method.

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Image resizing by Lagrange and de la Vallée Poussin type interpolation

Woula Themistoclakis (CNR National Research Council of Italy, IAC - Istituto per le Applicazioni del Calcolo "Mauro Picone", Napoli, Italy.), Donatella Occorsio, Giuliana Ramella*

The aim of this talk is to show how classical approximation tools such as Lagrange interpolation and more generally de la Vallée Poussin type interpolation, both of them based on Chebyshev zeros of first kind, can be fruitfully applied for resizing an arbitrary digital image. By means of such operators, we get image scaling methods running for any scale factor or desired size, in both downscaling and upscaling. The performance of such interpolation methods is discussed by several numerical experiments and some theoretical estimates of the mean squared error.

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Sampling Kantorovich operators for the detection of brain pathologies

Arianna Travaglini (University of Perugia), Danilo Costarelli, Marco Seracini, Gianluca Vinti*

Among sampling-type operators, the Sampling Kantorovich operator represents a useful tool for dealing with discontinuous functions [2]. Its muldimensional version has been implemented and allows not only to reconstruct, but also to enhance the resolution of images, as it acts as a low-pass filter [4]. Indeed, Sampling Kantorovich operators have been used, with satisfactory results, to both biomedical and engineering fields [1, 3].
The talk is focused on some recent results, which consist in the use of different algorithms, including Sampling Kantorovich operator, to process magnetic resonance images for the identification of indicators or biomarkers for Alzheimer's disease. The quality of reconstruction and the segmentation were both evalueted, comparing the volumetric values of the images processed with the various algorithms, with the ground truth values, considered as reference.

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A mathematical model for the reconstruction of digital images: a brief overview of the results of the Perugia research group

Gianluca Vinti (University of Perugia), Danilo Costarelli, Marco Seracini, Gianluca Vinti*

In this talk, I present a mathematical model for the reconstruction of digital images based on approximation processes of discrete operators of sampling type ([2, 5]). The model has been successfully applied in various fields, medical, engineering, environmental. I will make a quick overview of the properties and of the applications of the model that enhance its effectiveness (see e.g., [1, 3, 4]).

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Order 4 and 6 Exponential-Polynomial PH Curves

Alberto Viscardi (Alma Mater Studiorum Università di Bologna), Lucia Romani*

A phytagorean-hodograph (PH) curve is a parametric polynomial curve for which the norm of its first derivative (hodograph) is also a polynomial. In this talk a generalization to exponential-polynomials is presented, with a focus on order 4 and order 6 curves. Algebraic and geometric characterizations are discussed together with the application to first order Hermite interpolation problems. A new fast and stable evaluation procedure is proposed and compared with existing algorithms.

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Adaptive BEM and Besov-type spaces based on wavelet expansions

Markus Weimar (Ruhr University Bochum, Germany), S. Dahlke, H. Harbrecht, M. Utzinger*

We study regularity properties of solutions to operator equations on patchwise smooth manifolds $\partial\Omega$ such as, e.g., boundaries of polyhedral domains $\Omega \subset \mathbb{R}^3$. Using suitable biorthogonal wavelet bases Ψ, we introduce a class of Besov-type spaces $B^{\alpha}_{\Psi,q}(L_p(\partial\Omega))$ of functions $u\colon \partial\Omega \to \mathbb{C}$. Special attention is paid on the rate of convergence for best n-term wavelet approximation to functions in these scales since this determines the performance of adaptive numerical schemes. We show embeddings of (weighted) Sobolev spaces on $\partial\Omega$ into $B^{\alpha}_{\Psi,\tau}(L_\tau(\partial\Omega))$, $1/\tau = \alpha/2 + 1/2$, which lead to regularity assertions for the equations under consideration. Finally, we apply our results to a boundary integral equation of the second kind which arises from the double layer ansatz for Dirichlet problems for Laplace's equation in Ω. The talk is based on a series of papers which arose from the DFG-Project "BIOTOP: Adaptive Wavelet and Frame Techniques for Acoustic BEM" (DA 360/19-1).

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POSTERS

FSK-PSK data processing based on direct approximation of the Hilbert transform

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We describe a signal processing method for demodulation of digital signals based on Hilbert transform (HT). We review the signal processing theory and the method of Analytic Signal transformation (AS) and their algorithms which are implemented by FFT, then we propose a direct method for the numerical approximation of the Hilbert transform [1]. The proposed algorithm provides the estimate of instantaneous frequency and phase of the received signals, and can be used for both binary communication based on phased-shifting keying (PSK) and frequency-shifting keying (BFSK) [2]. Typical applications include the data communication of seismic soil response or the actuation and sensing between underground energy autonomous platforms and sea floating stations, or related data analysis as a bank of matched filters [3].

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On the selection of the shape parameter in RBF interpolation using univariate global optimization methods

Roberto Cavoretto (University of Torino, Italy), A. De Rossi, M. S. Mukhametzhanov, Ya. D. Sergeyev*

We consider the problem of finding an optimal value of the shape parameter in radial basis function interpolation (see e.g. [2]). In particular, we propose the use of a leave-one-out cross validation (LOOCV) technique [3] combined with univariate global optimization methods, which involve strategies of Global Optimization with Pessimistic Improvement (GOPI) and Global Optimization with Optimistic Improvement (GOOI) [4]. This choice is done to overcome the serious issues of the commonly used optimization routines that sometimes lead to shape parameter values quite distant from being globally optimal. Numerical experiments show performance and efficacy of our new algorithms, called LOOCV-GOPI and LOOCV-GOOI [1].

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Fuzzy fractional-order model and COVID-19 dynamics

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In this work, a novel COVID-19 infection system with a fuzzy fractional differential equation (FDEs) defined in Caputo's sense is developed. By using the fuzzy Laplace method coupled with Adomian decomposition transform, numerical results are obtained for better understanding of the dynamical structures of the physical behavior of COVID-19. Such behavior on the general properties of RNA in COVID-19 is also investigated for the governing model. The results demonstrate the efficiency of the proposed approach to address the uncertainty condition in the pandemic situation. Some researchers put their focus on the transmission of 2019-nCoV virus among humans and its identification. It's well accepted that human-to-human transmission is leading to the rapid growth of infections. Ahmed claimed that viral strains from the infected people of the area have been sequenced; but only little genetic variation was found, implying that they have descended from a common ancestor. On the other hand, Zhou argued that sequences of the seven conserved viral replicase domains in ORF 1ab show 94.6 percent similarity in 2019-nCoV and SARS-CoV. Chaudhury et al. proved that computational protein protein docking with accurate, physics-based energy functions is able to reveal the native-like, low-energy protein complex from the unbound structures of two individual, interacting protein components. In our work we try to investigate 2019-nCoV infection system mathematically.In the last part of the work, it will be issued some new addressing research fields strictly related to the FDEs and related developments involved in ongoing studies.

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Hopf Bifurcations, Dynamics and Economic Modeling

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In this talk we will examine the consequences of including distributed delays in an energy model. In particular, we will present a model that has been developed starting from C.L. Dalgaard and H. Strulik's model (2011), a mathematical model of an economy viewed as a transport network for energy. The new model has been developed by C. Bianca et al. (2013a), modifying the model by C.L. Dalgaard and H. Strulik (2011) with the assumption that the energy conservation formula would be influenced by a time delay; they have showed that the dynamics of the system is characterized by a delay differential equation. The stability behaviour of the resulting equilibrium for our dynamic system is analyzed including models with Dirac, weak and strong kernels. Applying the Hopf bifurcation theorem we will determine conditions under which limit cycle motion is born in such models. The results indicate that distributed delays have an ambivalent impact on the dynamical behaviour of systems, either stabilizing or destabilizing them. Afterwards, based on V.I. Yukalov et al. (2009), C. Bianca et al. (2013b) have adapted their ideas and proposed a generalization by introducing a logistic-type equation for population with delayed carrying capacity. In their study they have analyzed the consequences of replacing time delays with distributed time delays. C. Bianca et al. (2013b) have showed that the destructive impact of the agents on the carrying capacity leads the system dynamic behaviour to exhibit stability switches and Hopf bifurcations to occur. Now we will organize a new proposal in this direction.

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Radial solutions to a nonconstant gradient constrained problem

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Our work deals with radial solutions to a nonconstant gradient constrained problem in a ball of $\mathbb{R}^n$ and with the Lagrange multipliers associated with the problem. The problem is formulated by means of a variational inequality and, under a suitable assumption, we obtain for $n = 2$ a necessary and sufficient condition, characterizing the free boundary. In particular, this condition allows us to define the explicit solution and the Lagrange multiplier. Finally, some examples illustrate the results.

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On Treating a Fractional Order Mathematical Model of COVID-19 and its variants Via Haar Wavelet Method

Domenica Stefania Merenda (Department of Law, Economics and Human Sciences & Decisions Lab Mediterranea University of Reggio Calabria, 89125, Italy), Massimiliano Ferrara*

The human society, facing of having modern and complicated technologies in each stage of life, is determined to fight a dangerous enemy, know as novel COVID-19. As compared to developing world this virus affected more extremely the developed countries. This virus was for the first time come into view in city of China, Wuhan. The statistics provided by World Health Organization (WHO) on 6th November 2020, COVID-19 affected great part of countries and territories around the globe.
If anyone with contact with the droplets emitted during the sneeze or cough of effected person is at risk to the virus attack. In order to prevent the transmission of spreading disease, all around the globe lock-down policy are implementing by all governments in their respective countries to ensure the safety of their citizens. In this circumstance, a lot of doctors, nurses and paramedics doctors and paramedics have committed themselves to provide services against the nCovid-2019. Experts compared the current virus with MERS and SARS to identify family of the virus to which it belongs so as to handle the current virus with the help of the studies done to deal with SARS and MERS in the past. Lu argued that the current nCovid-2019 relates to Beta-corona virus genus, like SARS-Cov and MERS-Cov.
This paper is devoted to investigate a fractional order mathematical model of the current novel Corona virus-19 infectious disease (COVID-19). Our investigation is devoted to existence theory and numerical approximation. For the required result of existence theory fixed point due to Shaufer's and Banach are used. Also for numerical analysis, Haar collocation (HC) techniques is used to handle the model under our consideration. Furthermore, it is noted that the derivative is taken in Caputo sense. For the respective numerical verification some available real data is used. Graphical interpretations corresponding to different compartments of the considered model against various fractional orders are given.

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Mixed Nyström and Collocation methods for Fredholm Integral Equations

Domenico Mezzanotte (University of Basilicata), Donatella Occorsio, Maria Grazia Russo*

The poster deals with the numerical solution of Fredholm Integral Equations (FIEs) of the following type

$$f(y) - \mu \int_{-1}^{1} f(x)k(x,y)\rho(x)\,dx = g(y), \quad y \in (-1,1),$$

where ρ is a Jacobi weight, g e k are known functions defined in $(-1,1)$ and $(-1,1)^2$ respectively, μ is a non zero real parameter and f is the unknown solution.
As new approach we propose a Mixed Nyström Method (MNM), employing ordinary and extended product integration rules, both of them based on Jacobi zeros. Stability and convergence of the method are proved in spaces of locally continuous functions, endowed with weighted uniform norms. Furthermore, we recall the Mixed Collocation Method (MCM) proposed in [1], which is a projection method based on the idea of alternatively using a Lagrange projector and an Extended Lagrange projector, both based on Jacobi zeros.
MCM and MNM allow to reduce the computational effort while preserving the same rate of convergence of their classical counterparts, other than delay the difficulties in the evaluation of the high degree zeros of the Jacobi polynomials. A comparison between the methods is proposed by highlighting their pros and cons.

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Improving the accuracy of quadrature formulas from equispaced nodes through the constrained mock-Chebyshev least squares interpolation.

Federico Nudo (University of Calabria), Francesco Dell'Accio, Filomena Di Tommaso*

The constrained mock-Chebyshev least squares interpolation is a univariate polynomial interpolation technique exploited to cut-down the Runge phenomenon. It takes advantage of the optimality of the interpolation on the mock-Chebyshev nodes, i.e. the subset of the uniform grid formed by nodes that mimic the behavior of Chebyshev–Lobatto nodes. The other nodes of the grid are not discarded, rather they are used in a simultaneous regression to improve the accuracy of the approximation of the mock-Chebyshev subset interpolant. In this work we apply the constrained mock-Chebyshev least squares interpolant to obtain quadrature formulas from equispaced nodes of various degree of exactness and accuracies. We also show how to predict the absolute error of approximation through the relative one computed by using formulas of subsequent degrees. Numerical experiments demostrate the effectiveness of such extensions.

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