

Domingo Barrera
Sara Remogna
Driss Sbibih *Editors*

Mathematical and Computational Methods for Modelling, Approximation and Simulation

SēMA

SIMAI
SOCIETÀ ITALIANA DI MATEMATICA
APPLICATA E INDUSTRIALE




Springer

SEMA SIMAI Springer Series

Volume 29

Editors-in-Chief

José M. Arrieta, Departamento de Análisis Matemático y Matemática Aplicada, Facultad de Matemáticas, Universidad Complutense de Madrid, Madrid, Spain

Luca Formaggia , MOX-Department of Mathematics, Politecnico di Milano, Milano, Italy

Series Editors

Mats G. Larson, Department of Mathematics, Umeå University, Umeå, Sweden

Tere Martínez-Seara Alonso, Departament de Matemàtiques, Universitat Politècnica de Catalunya, Barcelona, Spain

Carlos Parés, Facultad de Ciencias, Universidad de Málaga, Málaga, Spain

Lorenzo Pareschi, Dipartimento di Matematica e Informatica, Università degli Studi di Ferrara, Ferrara, Italy

Andrea Tosin, Dipartimento di Scienze Matematiche “G. L. Lagrange”, Politecnico di Torino, Torino, Italy

Elena Vázquez-Cendón, Departamento de Matemática Aplicada, Universidade de Santiago de Compostela, A Coruña, Spain

Paolo Zunino, Dipartimento di Matematica, Politecnico di Milano, Milano, Italy

As of 2013, the SIMAI Springer Series opens to SEMA in order to publish a joint series aiming to publish advanced textbooks, research-level monographs and collected works that focus on applications of mathematics to social and industrial problems, including biology, medicine, engineering, environment and finance. Mathematical and numerical modeling is playing a crucial role in the solution of the complex and interrelated problems faced nowadays not only by researchers operating in the field of basic sciences, but also in more directly applied and industrial sectors. This series is meant to host selected contributions focusing on the relevance of mathematics in real life applications and to provide useful reference material to students, academic and industrial researchers at an international level. Interdisciplinary contributions, showing a fruitful collaboration of mathematicians with researchers of other fields to address complex applications, are welcomed in this series.

THE SERIES IS INDEXED IN SCOPUS

Domingo Barrera • Sara Remogna • Driss Sbilih
Editors

Mathematical and Computational Methods for Modelling, Approximation and Simulation

 Springer

Editors

Domingo Barrera 
Department of Applied Mathematics
University of Granada
Granada, Spain

Sara Remogna
Dipartimento di Matematica “Giuseppe
Peano”
Università degli Studi di Torino
Torino, Italy

Driss Sbibih
Faculty of Sciences, LANO Laboratory
Mohammed First University
Oujda, Morocco

ISSN 2199-3041

ISSN 2199-305X (electronic)

SEMA SIMAI Springer Series

ISBN 978-3-030-94338-7

ISBN 978-3-030-94339-4 (eBook)

<https://doi.org/10.1007/978-3-030-94339-4>

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG 2022

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

This volume contains three plenary lectures presented at the International Conference on Mathematical and Computational Modelling, Approximation and Simulation (MACMAS 2019) which was held from 9 to 11 September 2019 in Granada, Spain, as well as nine contributed papers from the different topics covered at the conference.

MACMAS 2019 was jointly organized by the University of Granada (Spain), the Mohammed I University (Morocco), and the University of Torino (Italy).

MACMAS is a new phase in the series of international conferences on approximation methods and numerical modelling in environment and natural resources held every 2 years from 2005 to 2017. The following are among its goals:

- Gather the researchers interested on the fields of approximation, numerical modelling, and their applications.
- Reinforce the scientific interchange between researches from different countries, with special emphasis on the Mediterranean basin and neighborhood.
- Encourage young researchers to present the results of their scientific works.
- Help new international research projects to arise by facilitating contacts between tentative partners.

Stefano De Marchi, Pablo Pedregal, and Alessandra Sestini gave plenary lectures, sharing their research results with the participants.

Stefano de Marchi is an associate professor at the University of Padova (Italy), with habilitation to Full Professor of Numerical Analysis. Since 2005, he has been the coordinator of the “CAA Research Group” (Constructive Approximation and Applications), between the Universities of Verona and Padova. In addition, he has been responsible of the Italian Mathematical Union Thematic Group on Approximation Theory and Applications. His current main research topics are mapped bases approximation, RBF variably scaled discontinuous kernels, RBF and meshless approximation, multivariate polynomial approximation, and cubature.

Stefano De Marchi’s plenary lecture dealt with the solution of approximation problems by polynomials to reduce Runge and Gibbs phenomena. The main idea is to avoid resampling the function or data and to rely on the mapped polynomials

or “fake” nodes approach. This technique turns out to be effective for stability by reducing the Runge effect and also in the presence of discontinuities by almost cancelling the Gibbs phenomenon. This technique is also applied to rational approximation and quadrature.

Pablo Pedregal obtained his bachelor’s degree in mathematics in Madrid (Universidad Complutense de Madrid, 1986), and he moved to the United States to pursue his PhD, obtained at the University of Minnesota at the end of 1989, under the direction of David Kinderlehrer. He is currently full professor at the University of Castilla-La Mancha after a period at the Complutense University of Madrid as associate professor. His field of work is variational techniques applied to optimization problems in a very broad sense, covering the calculus of variations, non-convex vector problems, optimal design in continuous media, and optimal control.

Pablo Pedregal’s plenary lecture focuses on two specific problems that show the enormous difficulties that arise when studying models that depend on the highly non-linear behavior of a system of partial differential equations. The first one is motivated by inverse problems in conductivity and the process to recover an unknown conductivity coefficient from measurements in the boundary. The second addresses an optimal control problem for soft robots. This paper has an outreach character to draw attention to these areas of research.

Alessandra Sestini is associate professor at the University of Firenze (Italy), with habilitation to Full Professor of Numerical Analysis. She has participated in several projects of the “Gruppo Nazionale per il Calcolo Scientifico,” having been the responsible researcher in 2012 and 2019. In recent years, she has also conducted her research into the 5-year project “Splines for accURate NumeRics: adaptIve models for Simulation Environments (SUNRISE)” of the INdAM *Istituto Nazionale di Alta Matematica «Francesco Severi»*. Her current research interests are numerical methods for approximation and for graphics, spline theory, numerical methods for ODEs, and isogeometric analysis.

Alessandra Sestini’s plenary lecture is a collaborative work with Cesare Bracco, Carlotta Giannelli, David Großmann, Sofia Imperatore, and Dominik Mokriš, in which they present a two-stage scattered data fitting with truncated hierarchical B-splines (THB-splines) for the adaptive reconstruction of industrial models. The first stage deals with the computation of local least squares variational spline approximations. The second one involves hierarchical spline quasi-interpolation based on THB-splines to construct the adaptive spline surface approximating the whole scattered data set, and a suitable strategy to guide the adaptive refinement is introduced. A selection of examples on geometric models representing components of aircraft turbine blades highlights the performance of the scheme.

Following the end of MACMAS 2019, a call for papers was opened. The submissions received underwent a peer-review process and nine manuscripts were retained for publication.

The chapters by Abbadì and Ibáñez and Rahouti et al. deal with the construction of univariate quasi-interpolants, which somewhat complement the results in the literature and offer approximation schemes potentially useful in practice. Quasi-

interpolation is a subject that has attracted and continues to attract the interest not only of those working in the field of approximation theory but also of those who require tools to be used in practice. An example of this is the chapter by Sestini. The chapters by Allouch et al., Bellour et al., and Barrera et al. use spline quasi-interpolation to numerically solve Fredholm and Hammerstein integral equations, which are relevant areas in terms of the application of numerical methods. The chapter by Mbarki and Oubrahim provides new results on the notion of convexity in probabilistic metric spaces, which are applied to the study of the existence and uniqueness of the solution of a Volterra equation. The chapter by Korikache and Paquet focuses on the completely discretized problem of the dual mixed formulation for the heat diffusion equation in a polygonal domain by the Crank-Nicolson scheme in time. The authors show the existence and the stability, and provide *a priori* error estimates for the solution. The chapter by Akhrif et al. proposes the application of smoothing splines to the study of decomposed statistical series. The general scheme is illustrated by applying it to economic data from Morocco and Venezuela. The chapter by Illescas-Manzano et al. deals with the analysis of poverty measures, which is a topic of increased interest to society. This chapter contributes to the literature by developing percentile ratio estimators when there are missing data.

We want to thank all the contributors who have coauthored the chapters contained in this volume, as well as the anonymous referees who have revised the manuscripts, improving them with their comments and suggestions.

We would also like to express our gratitude to Francesca Bonadei from Springer for her patience, attention, and support at every step of the editorial process.

Granada, Spain
Torino, Italy
Oujda, Morocco
April 2021

Domingo Barrera
Sara Remogna
Driss Sbibih

Contents

Part I Plenary Lectures

1	Mapped Polynomials and Discontinuous Kernels for Runge and Gibbs Phenomena	3
	Stefano De Marchi	
2	Steady Systems of PDEs. Two Examples from Applications	45
	Pablo Pedregal	
3	THB-Spline Approximations for Turbine Blade Design with Local B-Spline Approximations	63
	Cesare Bracco, Carlotta Giannelli, David Großmann, Sofia Imperatore, Dominik Mokriš, and Alessandra Sestini	

Part II Contributed Papers

4	A Progressive Construction of Univariate Spline Quasi-Interpolants on Uniform Partitions	85
	Abdelaziz Abbadi and María José Ibáñez	
5	Richardson Extrapolation of Nyström Method Associated with a Sextic Spline Quasi-Interpolant	105
	Chafik Allouch, Ikram Hamzaoui, and Driss Sbibih	
6	Superconvergent Methods Based on Cubic Splines for Solving Linear Integral Equations	121
	Azzeddine Bellour, Driss Sbibih, and Ahmed Zidna	
7	The Completely Discretized Problem of the Dual Mixed Formulation for the Heat Diffusion Equation in a Polygonal Domain by the Crank-Nicolson Scheme in Time	143
	Reda Korikache and Luc Paquet	

8	Economic Statistical Splicing Data Using Smoothing Quadratic Splines	163
	Rim Akhrif, Elvira Delgado-Márquez, Abdelouahed Kouibia, and Miguel Pasadas	
9	Some Properties of Convexity Structure and Applications in b-Menger Spaces	181
	Abderrahim Mbarki and Rachid Oubrahim	
10	A Super-Superconvergent Cubic Spline Quasi-Interpolant	191
	Afaf Rahouti, Abdelhafid Serghini, Ahmed Tijini, and Ahmed Zidna	
11	Calibration Adjustment for Dealing with Nonresponse in the Estimation of Poverty Measures	209
	María Illescas-Manzano, Sergio Martínez-Puertas, María del Mar Rueda, and Antonio Arcos-Rueda	
12	Numerical Methods Based on Spline Quasi-Interpolating Operators for Hammerstein Integral Equations	237
	Domingo Barrera, Abdelmonaim Saou, and Mohamed Tahrichi	