

# Preface

The multidisciplinary STEAM-H series (Science, Technology, Engineering, Agriculture, Mathematics, and Health) brings together leading researchers to present their own work in the perspective to advance their specific fields and in a way to generate a genuine interdisciplinary interaction transcending disciplinary boundaries. All chapters therein were carefully edited and peer-reviewed; they are reasonably self-contained and pedagogically exposed for a multidisciplinary readership.

Contributions are by invitation only and reflect the most recent advances delivered in a high standard, self-contained way. The goals of the series are :

- (1) To foster student interest in science, technology, engineering, agriculture, mathematics and health.
- (2) To enhance multidisciplinary understanding between the disciplines by showing how some new advances in a particular discipline can be of interest to the other discipline, or how different disciplines contribute to a better understanding of a relevant issue at the interface of mathematics and the sciences.
- (3) To promote the spirit of inquiry so characteristic of mathematics for the advances of the natural, physical, and behavioral sciences by featuring leading experts and outstanding presenters.
- (4) To encourage diversity in the readers' background and expertise, while at the same time structurally fostering genuine interdisciplinary interactions and networking.

Current disciplinary boundaries do not encourage effective interactions between scientists; researchers from different fields usually occupy different buildings on university campuses, publish in journals specific to their field, and attend different scientific meetings. Existing scientific meetings usually fall into either small gatherings specializing on specific questions, targeting specific and small group of scientists already aware of each other's work and potentially collaborating, or large meetings covering a wide field and targeting a diverse group of scientists but usually not allowing specific interactions to develop due to their large size and a crowded program. Traditional departmental seminars are becoming so technical as to be largely inaccessible to anyone who did not coauthor the research being presented.

Here, contributors focus on how to make their work intelligible and accessible to a diverse audience, which in the process enforces mastery of their own field of expertise.

In honor of Professor Rousseau, a pioneer of mathematical approaches to human earthly challenges, this volume strongly advocates multidisciplinary with the goal to generate new interdisciplinary approaches, instruments, and models including new knowledge, transcending scientific boundaries to adopt a more holistic approach. For instance, it should be acknowledged, following Nobel Laureate and President of the UK's Royal Society of Chemistry, Professor Sir Harry Kroto, "that the traditional chemistry, physics, biology departmentalised university infrastructures—which are now clearly out-of-date and a serious hindrance to progress—must be replaced by new ones which actively foster the synergy inherent in multidisciplinary." The National Institutes of Health and the Howard Hughes Medical Institute have strongly recommended that undergraduate biology education should incorporate mathematics, physics, chemistry, computer science, and engineering until "interdisciplinary thinking and work become second nature." Young physicists and chemists are encouraged to think about the opportunities waiting for them at the interface with the life sciences. Mathematics is playing an ever more important role in the physical and life sciences, engineering, and technology, blurring the boundaries between scientific disciplines.

The series is to be a reference of choice for established interdisciplinary scientists and mathematicians and a source of inspiration for a broad spectrum of researchers and research students, graduate, and postdoctoral fellows; the shared emphasis of these carefully selected and refereed contributed chapters is on important methods, research directions, and applications of analysis including within and beyond mathematics. As such, the volume promotes mathematical sciences, physical and life sciences, engineering, and technology education, as well as interdisciplinary, industrial, and academic genuine cooperation.

Toward such goals, the following chapters are featured in the current volume.

Chapter 1 by Faina Berezovskaya, studies a FitzHugh model modified to include a cross-diffusion connection between the potential and recovery variables, investigating successful propagation of an excitable neuron but also propagation failures, which are extremely important for many applications. The model demonstrates two types of behaviors, so-called "slow" and "fast" traveling waves.

Chapter 2 by Terence Blows, outlines a simple but imperfect approach to the study of degenerate foci and uses the method to give an example of a cubic system with four local limit cycles about a degenerate focus.

In Chap. 3 by Pietro-Luciano Buono and Raluca Eftimie, the authors establish the applicability of the Lyapunov–Schmidt reduction and the Centre Manifold Theorem for a class of hyperbolic partial differential equation models with nonlocal interaction terms describing the aggregation dynamics of animals/cells in a one-dimensional domain with periodic boundary conditions.

Chapter 4 by Magdalena Caubergh and Robert Roussarie, deals with relaxation oscillations from a generic balanced canard cycle subjected to three breaking

parameters of Hopf or jump type and proves that at most five relaxation oscillations bifurcate in a rescaled layer of the cycle.

In Chap. 5 by Colin Christopher, Wuria Muhammad Ameen, and Zhaoxia Wang, the authors first present cases where all integrability conditions are either uncovered by Darboux method or by a monodromic argument, and then investigate the integrability of the critical points which do not lie at the origin.

Chapter 6 by Morgan Craig, Mario González-Sales, Jun Li, and Fahima Nekka is a study to substantiate and situate the use of physiological modeling in pharmacometrics and provide incentives to continue to improve understanding of the underlying physiological mechanisms of a given system. It is also a testimony to the necessity of building bridges between diverse actors from different backgrounds (pharmaceutical scientists, clinicians, biomathematician, statisticians, engineers, etc.) in the pharmaceutical community to best serve patients and their needs.

Chapter 7 by Bui Xuan Dieu, Luu Hoang Duc, Stefan Siegmund, and Nguyen van Minh, is concerned with the strong stability of solutions of a class of non-autonomous equations with an unbounded operator in a Banach space and almost periodically time-dependent. A general condition on strong stability is given in terms of Perron conditions on the solvability of the associated inhomogeneous equation.

Chapter 8 by Mohamed El Morsalani and Abderaouf Mourtada, presents a new approach to the problem of limit cycles, which appear near hyperbolic polycycles of vector fields, upon a small deformation. Namely, the authors show a “preparation theorem” for quasi-regular functions, which appear as return maps associated to deformations of hyperbolic polycycles.

Chapter 9 by Raymond Fletcher, studies cubic curves that invert onto themselves, stemming for an investigation of group circle systems.

Chapter 10 by Lili Guadarrama, presents an emerging technique for noninvasive imaging with broad application in several disciplines including biomedical imaging and nondestructive testing. It summarizes different approaches for the imaging technique of elastography : quasi-static, harmonic, and transient elastography, along with establishing models for viscoelasticity.

Chapter 11 by Gerard Kientega is a chapter that studies affine completeness of algebras using a generalized metric to prove an extension theorem leading to new results such as an answer to a question of Karli and Pixley.

In Chap. 12 by Bernd Krauskopf and Hinke M. Osinga, the authors review how a conjectural codimension-four unfolding of the full family of cubic Liénard equations helps to identify the central singularity as an excellent candidate for the organizing center that unifies different types of spiking action potentials of excitable cells. This point of view and the subsequent numerical investigation of the respective bifurcation diagrams led, in turn, to new insight on how this codimension-four unfolding manifests itself as a sequence of bifurcation diagrams on the surface of a sphere.

Chapter 13 by Yu Ilyashenko considers the long and glorious history of the theory of planar bifurcations which one could initially split into two parts : one part on local bifurcations such as the Poincaré–Andronov–Hopf bifurcation and another part on

nonlocal bifurcations dealing with the bifurcations of separatrix polygons and the polycycles such as separatrix loops of hyperbolic saddles and homoclinic curves of saddle-nodes. The chapter shows that there is a third part, not yet developed, that may be called “global bifurcations,” the main features being termed “sparking bifurcations.” They were discovered by Malta-Palis in the 1980s.

Chapter 14 by Chengzhi Li first introduces some basic concepts about slow-fast dynamics and its application to a biological model, a predator–prey system with response functions of Holling type, and a medical model, a SIS epidemic model with nonlinear incidence.

Chapter 15 by Pavao Mardesic, Dominique Sugny, and Leo van Damme, exposes the key role played by Abelian integrals in the infinitesimal version of the Hilbert 16th problem, as well as in the study of Hamiltonian monodromy of fully integrable systems. The authors treat in particular the simplest example presenting nontrivial Hamiltonian monodromy : the spherical pendulum.

Chapter 16 by Thanh Nguyen, Debarun Kar, Matthew Brown, Arunesh Sinha, Albert XinJiang, and Milind Tambe, the authors present how security is a critical concern around the world and computational game theory can help design security schedules in many domains from counterterrorism to sustainability where limited security resources prevent full security coverage at all times ; casting the problem as a Bayesian Stackelberg game, the authors developed new algorithms that are now deployed over multiple years in multiple applications for security scheduling. These applications are leading to real-world use-inspired research in the emerging research area of “security games”; specifically, the research challenges posed by these applications include scaling up security games to large-scale problems, handling significant adversarial uncertainty, dealing with bounded rationality of human adversaries, and other interdisciplinary challenges.

Chapter 17 by Michael Pohrivchak, John Adam, and Umaphorn Nuntaplook starts off with a nice review discussing some of the seminal advances of the last few centuries and their relation to electromagnetic radiation scattering off spheres of varied sizes, and then continues with an investigation of the backscattering of inhomogeneous spheres with different refractive index profiles, which affect the reflection, refraction, and diffraction properties of the spheres, following the approach of Uslenghi and Weston by making use of a modified Watson transformation.

Chapter 18 by Martha Alvarez Ramirez and Rodríguez José Antonio García, reviews the relations between Hamiltonian systems and symplectic geometry and uses these relations to reduce the system degrees of freedom, leading, in particular, to the solutions of the 2-body problem.

Chapter 19 by Anthony Ruffa, Michael Jandron, and Bourama Toni, presents an approach that can support a parallelized solution of banded linear systems without communication between processors using a scheme based on adjoining as many unknowns as the number of superdiagonals. The chapter also introduces p-adic computation, a step toward the development and implementation of a full parallel p-adic linear solver.

In Chap. 20 by Laban Rutto, Vitalis Temu, and Myong-Sook Ansari, the authors address the question of genetic loss and erosion of indigenous food cultures as

a preamble to making a case for investment in research on underutilized and alternative crops. Here is an area of research that could greatly benefit from an interdisciplinary approach to include mathematical and statistical models.

Chapter 21 by Mahlet Tadesse, Frederic Mortier, and Stefano Monni, reviews frequentist and Bayesian methods proposed to address in a unified manner the problems of cluster identification and cluster-specific variable selection in the context of mixture of regression models and also in the context of high-dimensional data analysis. Illustrations of these method performances are taken from ecology for modeling species-rich ecosystems and from genomic for integrating data from different genomic sources.

Chapter 22 by Loïc Teysier addresses more precisely germs of parametric families of vector fields in the complex plane, with a saddle-node bifurcation and corresponding to first-order non linear differential equations.

Chapter 23 by Henryk Zoladek presents a new and corrected proof of the existence of 11 small amplitude limit cycles in a perturbation of some special cubic plane vector field with center.

The book as a whole certainly enhances the overall objective of the series, that is, to foster student interest and enthusiasm in the STEAM-H disciplines (Science, Technology, Engineering, Agriculture, Mathematics, and Health), stimulate graduate and undergraduate research, and generate collaboration among researchers on a genuine interdisciplinary basis.

The STEAM-H series is hosted at Virginia State University, Petersburg, Virginia, USA, an area that is socially, economically, intellectually very dynamic, and home to some of the most important research centers in the USA, including NASA Langley Research Center, manufacturing companies (Rolls-Royce, Canon, Chromalloy, Sandvik, Siemens, Sulzer Metco, NN Shipbuilding, Aerojet) and their academic consortium (CCAM), University of Virginia, Virginia Tech, the Virginia Logistics Research Center (CCAL), Virginia Nanotechnology Center, The Aerospace Corporation, C3I Research and Development Center, Defense Advanced Research Projects Agency, Naval Surface Warfare Center, Thomas Jefferson National Accelerator Facility, and the Homeland Security Institute.

The STEAM-H series, by now well established with a high impact through its intensive seminars and books published by Springer a world-renown publisher, is expected to become a national and international reference in interdisciplinary education and research.



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