Preface

This multidisciplinary book brings together leading researchers in the STEAM-H disciplines (Science, Technology, Engineering, Agriculture, Mathematics and Health) 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, peer-reviewed; they are reasonably self-contained and pedagogically exposed for a multidisciplinary readership.

Contributions are invited only, and reflect the most recent advances delivered in a high standard, self-contained. The goals are:

1. To foster student interest in science, technology, engineering, agriculture, mathematics, and health.
2. To enhance multidisciplinary understanding between the disciplines, including through a participative seminar series 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 attendees and 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, accessible to a diverse audience, which in the process enforces mastery of their own field of expertise.

This volume strongly advocates multidisciplinarity 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 multidisciplinarity." 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.

This book will 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.

Towards such goals the following chapters are featured in the current volume.

Chapter "Controlling Chaos in the Heart: Some Mathematics Behind Terminating Cardiac Arrhythmia" by John W. Cain describes two vastly different methods for controlling cardiac arrhythmia and how those methods can be modeled mathematically. The traditional method, point stimulation, involves the delivery of spatially localized electrical shocks through the tip of an electrode, and is the basis for medical devices such as the implantable cardioverter defibrillator (ICD). A newer approach, known as far-field pacing (FFP), involves application of a pulsed electric field across the entire heart. FFP exploits tissue heterogeneity, such as interfaces between regions of healthy cells and dead (electrically non-conducting) ones, as a means of creating "virtual electrodes."

Chapter " Working Memory and Transfer: Theoretical and Practical Considerations" by Susanne M. Jaeggi and Martin Buschkuehl provides evidence for the efficacy of several working memory interventions developed in their laboratories and reviews the emerging literature from other groups. It discusses data that demonstrate transfer to non-trained tasks throughout the lifespan, that is, in young

adults, in old adults, in typically developing children, as well as children with Attention-Deficit Hyperactivity Disorder (ADHD). It also presents the neural correlates that underlie improvements observed with working memory training. The authors argue that, even though transfer effects can be elusive, and some of the effects seemingly not easy to replicate, instead of taking inconsistencies as a proof for a lack of efficacy, researchers need to develop innovative approaches to move the cognitive training literature beyond the simple question of whether or not training is effective, and to address questions of underlying mechanisms, individual differences, and training features and parameters that might mediate and moderate the efficacy of training.

Chapter "Partial Functional Differential Equations, Reduction of Complexity and Applications" by Khalil Ezzinbi aims at reducing the complexity of partial functional differential equations, assuming that the undelayed part is not necessarily densely defined and satisfies the Hille-Yosida condition. The delayed part is continuous. The author proves the dynamic of solutions are obtained through an ordinary differential equation that is well-posed in a finite dimensional space. He then shows the existence of almost automorphic solutions for partial functional differential equations. For illustration, he provides an application to the Lotka-Volterra model with diffusion and delay.

Chapter "Characterizations of Convex Quadrics in Terms of Midsurfaces and Shadow-Boundaries" by Valeriu Soltan discusses the middle points of any family of parallel chords of a real quadric surface in the Euclidean space R^n known to belong to a hyperplane, property holding as well for the shadow-boundaries of that surface. The author reviews the existing results and adds some new ones which characterize convex quadrics among convex hypersurfaces in R^n, possibly unbounded, in terms of plane quadric sections, hyperplanarity of their midsurfaces and shadow-boundaries.

Chapter "Classifying Normal, Nevus, and Primary Melanoma Skin Samples Using Penalized Ordinal Regression" by Kellie J. Archer, Jiayi Hou, and André A.A. Williams looks into translational research that is developing multigenic classifiers using data from high-throughput genomic experiments. While often the class to be predicted is nominal, sometimes it may be inherently ordinal. For example, tissue samples may be collected with the goal of classifying them as normal < pre-malignant < malignant. In this case, molecular features monotonically associated with the ordinal response may be important to disease development. While one can apply nominal response classification methods to ordinal response data, in so doing some information is lost that may improve the predictive performance of the classifier. The authors developed an R package, glmpathcr, capable of fitting a penalized continuation ratio model when the outcome to be predicted is ordinal. And they demonstrate application of their method by predicting progression to melanoma using microarray gene expression data.

Chapter "Structure–Activity Relationship Analysis of 7-Deazaadenosines as Anticancer Agents" by Josue A. Nava-Bello, Ewa Wasilewski, Angelica M. Bello, and Alejandro A. Nava-Ocampo considers the lengthy and costly complex process to develop a successful therapeutic. In order to accelerate this process, molecular

modeling has become a key component of drug design. Methods used in computational chemistry vary from *ab initio* quantum chemistry methods to semi-empirical calculations and molecular mechanics. A study of the anticancer activity of a series of 7-aryl- and 7-hetaryl-7-deazaadenosines showed that nucleosides with 5-member heterocycles at the position 7 were more potent *in vitro* cytostatic agents against hematological and solid tumor cell lines than molecules with 6-member heterocycles. The authors present a quantitative structure–activity relationship (QSAR) analysis of these chemical moieties in order to have a better understanding of their structural properties and identify their molecular descriptors explaining their biological activities. They found that 5-member cyclic structures have three energy molecular descriptors that were negatively correlated to their biological activity, in particular, compounds with higher energies had higher biological potency represented by lower IC_{50} values. CLogP, a parameter of lipophilicity, was also found to be positively correlated to their biological activity, i.e., compounds with lower CLogP values had higher biological potency represented by lower concentrations inhibiting the growth of cancer cells by 50 %. Qualitatively, 5-member-ring heterocycles of 7-deazaadenosine had lower steric hindrance, i.e., were structurally smaller, than their 6-member counterparts. They made the case that, such a context, a QSAR analysis could be extraordinarily helpful in studying the mode of action of molecules with potential pharmacological or toxicological relevance.

Chapter "More than an African American Facilitator and a Prayer: Integrating Culture and Community into HIV Prevention Programs for African American Girls" by Faye Z. Belgrave, Jasmine Abrams, Sarah Javier, and Morgan Maxwell focuses on the need for prevention and intervention programs to address health disparity within a culturally sensitive and developmentally appropriate framework, in the case of sexually active African American adolescent females at a heightened risk for contracting sexually transmitted infections including HIV/AIDS. Research has shown that culturally integrated interventions can be effective at reducing HIV risk The goals of this chapter are to: (1) define culture, cultural competency, and cultural integration; (2) discuss community integration in HIV prevention programs; and (3) discuss ways in which culture can be attended to and integrated in prevention and intervention efforts. The chapter addresses each goal in order, beginning with an overview of relevant concepts.

Chapter "Dynamics of Niche Construction in Models 'Consumers-Renewable Resource' and 'Prey-Predators-Renewable Resource'" by Faina S. Berezovskaya and Georgiy P. Karev deals with the question of "how much over-consumption a renewable resource can tolerate" using mathematical models, where a consumer population compete for the common resource, can contribute to resource restoration, and is subject to attacks of predators. The bifurcation analysis of the systems shows that well-adapted predators can keep the system in a stable equilibrium even for "strong" prey over-consumption, when the initial system of resource-consumer goes extinct. It means that predators may extend the domain of the total system coexistence.

Chapter "Recent Advances in Approaches to the Study of Gene Locus Control Regions" by Benjamin D. Ortiz contributes to the decades long investigation into the regulation of gene transcription in vertebrates, with the locus control region (LCR) emerging as perhaps the most powerful *cis*-acting regulatory DNA element that one can envision. An LCR element is unique in that it supports both specific spatiotemporal regulation of transcription during development and a poorly understood "insulation capacity" that prevents genomic interference with the gene regulatory program it would impose upon a linked transgene. As such, it represents a complete, compact, and portable package of the DNA sequence information required to establish an independently and predictably regulated gene locus in native chromatin of a whole animal. Both *in vivo* and cell culture models have contributed significantly to building the field of LCRs. Nevertheless, the gold standard experimental approach to LCR study is transgenic mice, which has been dominant in the progress made in the field over the past 25 years. However, recent technological advances are resulting in a re-emergence of cell culture-based approaches to LCR study, portending a coming era of more rapid progress in this significant but understudied field. The investigation of the unique and powerful gene regulatory activities supported by LCR elements offers unparalleled opportunities to gain insight into *cis*-mediated transcriptional regulation at the single gene locus level. Furthermore, such insights are critical to advancing the safety and efficacy of gene therapy.

Chapter "Dynamical Roles of Jacobian Feedback Loops and Qualitative Modeling" by Bourama Toni presents a mathematical methodology for the qualitative modeling of differential systems using the feedback loops encoded in the Jacobian matrix, and described by the products of the Jacobian entries under cyclic permutations of the indices. The technique is easy to implement and could quickly demarcate both parameter and phase spaces into exciting regions (limit cycle, multiple equilibria, chaotic behavior), non-exciting ones (single stable fixed points), hard-instance regions (ergodic behavior). As such it could be useful in surveying dynamical responses of models simulating physico-chemical, biological, biochemical, economical systems and game theory. It efficiently asserts the possibility of multistationarity, periodicity, self-sustained oscillations, chaotic behavior using strictly the qualitative relations and assumptions of the systems, to achieve primarily qualitative understanding rather than quantitative numerical prediction. To illustrate the author includes a complete loop analysis of the celebrated Lorenz and Rossler systems predicting their global dynamics.

Chapter "Forecasting of Time Series Data Using Multiple Break Points and Mixture Distribution" by Rajan Lamichhane, Norou Diawara, and Cynthia M. Jones deals with special classes of stochastic processes with time series of sparse data. Studies in such cases focus on the analysis, construction, and prediction in parametric models. Here, the authors assume several nonlinear time series with additive noise components, and the model fitting is proposed in two stages. The first stage identifies the density using all the clusters information, without specifying any prior knowledge of the underlying distribution function of the time series. In the second stage, they partition the time series into consecutive non-overlapping

intervals of quasi stationary increments where the coefficients shift from one stable regression relationship to a different one using a breakpoints detection algorithm. These breakpoints are estimated by minimizing the likelihood from the residuals. The authors approach time series prediction through the mixture distribution of combined error components. Parameter estimation of mixture distribution is done by using the EM algorithm. The method is then applied to a simulated data.

Chapter "Direct Differentiation of Human Pluripotent Stem Cells into Advanced Spermatogenic Cells: In Search of an *In Vitro* System to Model Male Factor Infertility" by Charles A. Easley, Calvin R. Simerly, and Gerald Schatten focuses on Assisted Reproductive Technology (ART) which has gained worldwide acceptance, and on Intracytoplasmic Sperm Injection (ICSI) which has aided couples with severe male factor infertility to achieve pregnancies. While ICSI has circumvented some defects in *in vitro* fertilization (IVF), numerous patients still fail to achieve pregnancies. Even with patients with known causes for male factor infertility (Klinefelter Syndrome, Sertoli Cell Only Syndrome, DAZ family deletions, etc.), root causes are still being investigated, although there is no *in vitro* model for human spermatogenesis to examine intracellular root causes. Differentiation of stem cells into spermatogenic lineages *in vitro* provides a unique window into the biological mechanisms responsible for driving pluripotent stem cells into essential progeny—haploid spermatids and viable sperm—as well as provides an innovative approach for determining novel root causes for male infertility. Our recent work outlined a novel approach for differentiating human embryonic stem cells (hESCs) and induced pluripotent stem cells (hiPSCs) into advanced spermatogenic lineages including haploid spermatids with correct parent-of-origin genomic imprints on two loci. The work provides herein a foundation for building a true *in vitro* model for human spermatogenesis with which to model, diagnose, and potentially treat male factor infertility.

Chapter "Stepanov-Like Pseudo-Almost Periodic Functions in Lebesgue Spaces with Variable Exponents $L^{p(x)}$" by Toka Diagana and Mohamed Zitane introduces and studies a new class of functions called Stepanov-like pseudo-almost periodic spaces with variable exponents, which generalizes in a natural way the space of Stepanov-like pseudo-almost periodic spaces. Basic properties of these new spaces are established. The existence of pseudo-almost periodic solutions to some first-order differential equations with $S^{p,q(x)}$-pseudo-almost periodic coefficients will also be studied.

Chapter "Group Circle Systems on Conics" by Raymond R. Fletcher studies a *group circle system*, a collection of points and circles in the Euclidean plane determined by the elements of an abelian group mapped injectively to the plane, where no five points in the range set are cocyclic. Here the attention is confined to group circle systems all of whose points (or vertices) lie on a noncircular conic.

Chapter "Remanufacturing Processes, Planning and Control" by Jianzhi Li and Zhenhua Wu provides a summary of critical issues in remanufacturing process and its planning and control. The chapter starts with an introduction of the special characteristics and the associated problems in remanufacturing. Typical remanufacturing processes such as cleaning, testing, and disassembly are then discussed in

detail. The chapter also provides a discussion of process sequencing for product disassembly to minimize cost and energy consumption. Due to the stochastic nature in the material arrival process, production planning represents another main challenge for remanufacturers. Based on a case study of a business in Austin TX, a simulation model with a prioritized stochastic batch arrival mechanism, considering factors that affect the total profit, is also discussed. The chapter also presents a genetic algorithm (GA) to optimize the production planning and control policies for dedicated remanufacturing.

The concluding chapter "Viscous Interfacial Motion: Analysis and Computation" by Jin Wang considers the interfacial flows between two viscous incompressible fluids. After formulating the mathematical framework, the author first presents analytical solutions to the linearized problem, discusses some results from linear asymptotic analysis, and then describes a numerical method for computing the nonlinear motion which ensures a high accuracy on and near the moving interface. Simulation results on viscous Stokes waves are presented to demonstrate the advantages of this method. In addition, as an example of nonlinear asymptotic study, the authors conduct a perturbation series analysis for Stokes waves with small viscosity, the results of which provide an analytical justification to the numerical observation.

The book as a whole will certainly enhance the overall objective of the series (seminars and previous volumes), 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.

Virginia State University is in 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, Aerospace Corporation, C3I Research and Development Center, Defense Advanced Research Projects Agency, Naval Surface Warfare Center, National Accelerator Facility, and the Homeland Security Institute. The series, the seminars and the written thematic continuation published by Springer a world-renowned publisher, is now well established and is expected to become a national and international reference in interdisciplinary STEAM-H education and research.

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Springer

http://www.springer.com/978-3-319-07754-3

New Frontiers of Multidisciplinary Research in STEAM-H (Science, Technology, Engineering, Agriculture, Mathematics, and Health)

Toni, B. (Ed.)

2014, XX, 389 p. 66 illus., 38 illus. in color., Hardcover
ISBN: 978-3-319-07754-3