

NONCONVEX OPTIMIZATION

For Signal Processing and Machine Learning

Worth a Look: Three New Imaging Technologies

A Green ICASSP 2020 in Virtual Barcelona

Closed-Form Output Response of Discrete-Time Linear Time-Invariant Systems Using Intermediate Auxiliary Functions

> Signal Processing



Contents

SPECIAL SECTION

NONCONVEX OPTIMIZATION For Signal Processing And Machine Learning

- 15 FROM THE GUEST EDITORS Anthony Man-Cho So, Prateek Jain, Wing-Kin Ma, and Gesualdo Scutari
- 18 UNDERSTANDING NOTIONS OF Stationarity in Nonsmooth Optimization

Jiajin Li, Anthony Man-Cho So, and Wing-Kin Ma

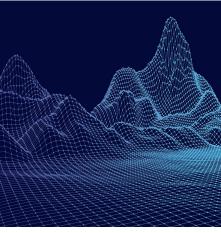
32 ADAPTIVE STOCHASTIC OPTIMIZATION Frank E. Curtis and

Katya Scheinberg

43 A PRIMER ON ZEROTH-ORDER OPTIMIZATION IN SIGNAL PROCESSING AND MACHINE LEARNING

Sijia Liu, Pin-Yu Chen, Bhavya Kailkhura, Gaoyuan Zhang, Alfred O. Hero III, and Pramod K. Varshney





<u>ON THE COVER</u>

This special issue introduces the essential elements of nonconvex optimization to the broader signal processing and machine learning communities, provides insights into how structures of the nonconvex formulations of various practical problems can be exploited in algorithm design, showcases some notable successes in this line of study, and identifies important research issues that are motivated by existing or emerging applications.

COVER IMAGE: ©ISTOCKPHOTO.COM/GAIHONG DONG

- 55 NONCONVEX MIN-MAX OPTIMIZATION Meisam Razaviyayn, Tianjian Huang, Songtao Lu, Maher Nouiehed, Maziar Sanjabi, and Mingyi Hong
- 67 NONCONVEX STRUCTURED PHASE RETRIEVAL Namrata Vaswani
 - Namrata Vaswani
- 78 COMPUTING LARGE-SCALE MATRIX AND TENSOR DECOMPOSITION WITH STRUCTURED FACTORS

Xiao Fu, Nico Vervliet, Lieven De Lathauwer, Kejun Huang, and Nicolas Gillis

95 THE GLOBAL LANDSCAPE OF NEURAL NETWORKS

Ruoyu Sun, Dawei Li, Shiyu Liang, Tian Ding, and Rayadurgam Srikant

109 GEOMETRY, MANIFOLDS, AND NONCONVEX OPTIMIZATION

Jonathan H. Manton

120 SUBMODULARITY IN ACTION

Ehsan Tohidi, Rouhollah Amiri, Mario Coutino, David Gesbert, Geert Leus, and Amin Karbasi

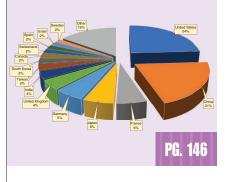
COLUMNS

6 Society News New Society Officers, Editors-in-Chief Elected for 2020 Election of Regional Directors-at-Large and Members-at-Large

8 Reader's Choice Top Downloads in IEEE Xplore

Ali H. Sayed

11 Special Reports Three New Imaging Technologies That Are Worth a Look Iohn Edwards



IEEE SIGNAL PROCESSING MAGAZINE (ISSN 1053-5888) (ISPREG) is published bimonthly by the Institute of Electrical and Electronics Engineers, Inc., 3 Park Avenue, 17th Floor, New York, NY 10016-5997 USA (+1 212 419 7900). Responsibility for the contents rests upon the authors and not the IEEE, the Society, or its members. Annual member subscriptions included in Society fee. Nonmember subscriptions available upon request. Individual copies: IEEE Members US\$20.00 (first copy only), nonmembers US\$246 per copy. Copyright and Reprint Permissions: Abstracting is permitted with credit to the source. Libraries are permitted to photocopy beyond the limits of U.S. Copyright Law for private use of patrons: 1) those post-1977 articles that carry a code at the bot-tom of the first page, provided the per-copy fee is paid through the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923 USA; 2) pre-1978 articles without fee. Instructors are permitted to photocopy isolated articles for noncommercial classroom use without fee. For all other copying, reprint, or republication permission, write to IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08854 USA. Copyright @ 2020 by the Institute of Electrical and Electronics Engineers, Inc. All rights reserved. Periodicals postage paid at New York, NY, and at additional mailing offices. Postmaster: Send address changes to IEEE Signal Processing Magazine, IEEE, 445 Hoes Lane, Piscataway, NJ 08854 USA. Canadian GST #125634188 Printed in the U.S.A.

Digital Object Identifier 10.1109/MSP.2020.3006644

134 Lecture Notes

Two Applications of Deep Learning in the Physical Layer of Communication Systems *Emil Björnson and Pontus Giselsson*

Closed-Form Output Response of Discrete-Time Linear Time-Invariant Systems Using Intermediate Auxiliary Functions *Chun-Lin Liu and Soo-Chang Pei*

146 Conference Highlights

A Green ICASSP 2020 in Virtual Barcelona Ana Perez-Neira and Xavier Mestre

152 SP Competitions

Unsupervised Anomaly Detection Using Intelligent and Heterogeneous Autonomous Systems Damian Campo, David Martin, and Lucio Marcenaro

Let There Be a Beam Wei Liu, Mohammad Reza Anbiyaei, Xue Jiang, Lei Zhang, and Lucio Marcenaro

DEPARTMENTS

- 3 From the Editor Reflections on Tutorials and Surveys Robert W. Heath Jr.
- 5 President's Message That This Nation, Under God, Shall Have a New Birth of Freedom Ahmed Tewfik

163 Dates Ahead



The IEEE Spoken Language Technology Workshop will take place in Shenzhen, China, 19–22 January 2021.



IEEE prohibits discrimination, harassment, and bullying. For more information, visit http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html.

EDITOR-IN-CHIEF

Robert W. Heath Jr.—The North Carolina State University, U.S.A.

AREA EDITORS

Feature Articles Matthew McKay—Hong Kong University of Science and Technology, Hong Kong SAR of China

Special Issues

Namrata Vaswani—Iowa State University, U.S.A.

Columns and Forum

Rodrigo Capobianco Guido—São Paulo State University (UNESP), Brazil Roberto Togneri—The University of Western

Australia

e-Newsletter

Ervin Sejdic—University of Pittsburgh, U.S.A. Social Media and Outreach

Tiago Henrique Falk—INRS, Canada

Special Initiatives

Andres Kwasinski–Rochester Institute of Technology, U.S.A.

Nuria Gonzalez Prelcic—The North Carolina State University, U.S.A.

EDITORIAL BOARD

Daniel Bliss-Arizona State University, U.S.A Danijela Cabric-University of California, U.S.A. Volkan Cevher—École polytechnique fédérale de Lausanne, Switzerland Mrityunjoy Chakraborty-Indian Institute of Technology, Kharagpur, India George Chrisikos-Qualcomm, Inc., U.S.A. Elza Erkip—New York University, U.S.A. Alfonso Farina—Leonardo S.p.A., Italy Yifan Gong-Microsoft Corporation, U.S.A. B. Vikrham Gowreesunker-Texas Instruments Inc., U.S.A. Joseph Guerci-Information Systems Laboratories, Inc., U.S.A. Nageen Himayat—Intel, U.S.A. Clem Karl-Boston University, U.S.A. Erik Larsson—Linköping University, Sweden David Love—Purdue University, U.S.A Maria G. Martini-Kingston University, U.K. Helen Meng-The Chinese University of Hong Kong, China Meinard Mueller—Friedrich-Alexander Universität Erlangen-Nürnberg, Germany Phillip A. Regalia–U.S. National Science Foundation Alejandro Ribeiro—University of Pennsylvania, U.S.A. Douglas O'Shaughnessy—INRS Universite de Recherche, Canada Osvaldo Simeone-Kings College London, U.K. Milica Stojanovic-Northeastern University, U.S.A Ananthram Swami, Army Research Labs, U.S.A. Jong Chul Ye-KAIST, South Korea Qing Zhao-Cornell University, U.S.A Josiane Zerubia-INRIA Sophia-Antipolis

Mediterranee, France

ASSOCIATE EDITORS—COLUMNS AND FORUM

IEEE Signal Processing Magazine

Ivan Bajic—Simon Fraser University, Canada Balázs Bank—Budapest University of Technology and Economics, Hungary

Panayiotis (Panos) Georgiou–University of Southern California, U.S.A.

Hana Godrich—Rutgers University, U.S.A. Yuan-Hao Huang—National Tsing Hua University, Taiwan

Euee Seon Jang—Hanyang University, South Korea

Piya Pal—University of California San Diego, U.S.A.

Vishal M. Patel—Rutgers University, U.S.A. Christian Ritz—University of Wollongong, Australia Changshui Zhang—Tsinghua University, China H. Vicky Zhao—Tsinghua University, China

ASSOCIATE EDITORS—e-NEWSLETTER

Tamir Bendory—Tel Aviv University, Israel Behnaz Ghoraani—Florida Atlantic University, U.S.A. Anubha Gupta—IIIT Delhi, India Alessio Medda—Georgia Tech Research Institute, U.S.A.

Irena Orovic—University of Montenegro, Podgorica Sarah Ostadabbas—Northeastern University, U.S.A.

ASSOCIATE EDITOR—SOCIAL MEDIA/OUTREACH Guijin Wang—Tsinghua University, China

IEEE SIGNAL PROCESSING SOCIETY

Ahmed Tewfik—President Athina Petropulu—President-Elect Fernando Pereira—Vice President, Conferences Shrikanth Narayanan—VP Education K.V.S. Hari—Vice President, Membership Sergio Theodoridis—Vice President, Publications Tülay Adalı—Vice President, Technical Directions

IEEE SIGNAL PROCESSING SOCIETY STAFF

William Colacchio—Senior Manager, Publications and Education Strategy and Services Rebecca Wollman—Publications Administrator

IEEE PERIODICALS MAGAZINES DEPARTMENT

Jessica Welsh, Managing Editor Geraldine Krolin-Taylor, Senior Managing Editor Janet Dudar, Senior Art Director Gail A. Schnitzer, Associate Art Director Theresa L. Smith, Production Coordinator Mark David, Director, Business Development -Media & Advertising Felicia Spagnoli, Advertising Production Manager Peter M. Tuohy, Production Director Kevin Lisankie, Editorial Services Director Dawn M. Melley, Staff Director, Publishing Operations

Digital Object Identifier 10.1109/MSP.2020.3006647

SCOPE: *IEEE Signal Processing Magazine* publishes tutorial-style articles on signal processing research and applications as well as columns and forums on issues of interest. Its coverage ranges from fundamental principles to practical implementation, reflecting the multidimensional facets of interests and concerns of the community. Its mission is to bring up-to-date, emerging, and active technical developments, issues, and events to the research, educational, and professional communities. It is also the main Society communication platform addressing important issues concerning all members.