

IEEE Signal Processing MAGAZINE

Volume 36 | Number 1 | January 2019

RECENT ADVANCES IN MUSIC SIGNAL PROCESSING

Audio and Beyond

Autonomous UAV Filming
in Dynamic Unstructured
Outdoor Environments

Paraconsistent
Feature Engineering

Efficient Floating-Point
Division for DSP Application

IEEE VIP Cup 2018 Student
Competition Highlights

Contents

Volume 36 | Number 1 | January 2019

SPECIAL SECTION

MUSIC SIGNAL PROCESSING

- 17 FROM THE GUEST EDITORS**
Meinard Müller, Bryan A. Pardo,
Gautham J. Mysore,
and Vesa Välimäki
- 20 AUTOMATIC MUSIC
TRANSCRIPTION**
Emmanouil Benetos, Simon Dixon,
Zhiyao Duan, and Sebastian Ewert
- 31 MUSICAL SOURCE SEPARATION**
Estefanía Cano, Derry FitzGerald,
Antoine Liutkus, Mark D. Plumbley,
and Fabian-Robert Stöter
- 41 DEEP LEARNING FOR
AUDIO-BASED MUSIC
CLASSIFICATION AND TAGGING**
Juhan Nam, Keunwoo Choi,
Jongpil Lee, Szu-Yu Chou,
and Yi-Hsuan Yang
- 52 CROSS-MODAL MUSIC RETRIEVAL
AND APPLICATIONS**
Meinard Müller, Andreas Arzti,
Stefan Balke, Matthias Dorfer,
and Gerhard Widmer



(a)



(b)

PG. 13



ON THE COVER

This issue of *IEEE Signal Processing Magazine* surveys recent advances in music processing with a focus on audio signals. Eleven articles cover topics including music analysis, retrieval, source separation, singing-voice processing, musical sound synthesis, and user interfaces, among others.

COVER IMAGE: ©ISTOCKPHOTO.COM/MOORSKY

- 63 AUDIOVISUAL ANALYSIS OF
MUSIC PERFORMANCES**
Zhiyao Duan, Slim Essid,
Cynthia C.S. Liem, Gaël Richard,
and Gaurav Sharma
- 74 MUSIC INTERFACES BASED
ON AUTOMATIC MUSIC
SIGNAL ANALYSIS**
Masataka Goto and
Roger B. Dannenberg
- 82 AN INTRODUCTION TO
SIGNAL PROCESSING FOR
SINGING-VOICE ANALYSIS**
Eric J. Humphrey, Sravana Reddy,
Prem Seetharaman, Aparna Kumar,
Rachel M. Bittner, Andrew Demetriou,
Sankalp Gulati, Andreas Jansson,
Tristan Jehan, Bernhard Lehner,
Anna Kruspe, and Luwei Yang

- 95 SPEECH-TO-SINGING VOICE
CONVERSION**
Karthika Vijayan, Haizhou Li,
and Tomoki Toda
- 103 MODEL-BASED DIGITAL PIANOS**
Balázs Bank and Juliette Chabassier
- 115 MAKING MUSIC MORE
ACCESSIBLE FOR COCHLEAR
IMPLANT LISTENERS**
Waldo Nogueira, Anil Nagathil,
and Rainer Martin
- 128 OPEN-SOURCE PRACTICES FOR
MUSIC SIGNAL PROCESSING
RESEARCH**
Brian McFee, Jong Wook Kim,
Mark Cartwright, Justin Salamon,
Rachel Bittner, and Juan Pablo Bello

COLUMNS

- 7 Society News**
2018 Member-at-Large and Regional
Director-at-Large Election Results
SPS Announces 2019 Class of Distinguished
Lecturers and Distinguished Industry Speakers
- 13 Special Reports**
Growing Security and Privacy Threats Inspire
New Approaches
John Edwards



PG. 164

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\$241.00 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 bottom of the first page, provided the per-copy fee indicated in the code 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 © 2019 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.2018.2877379

138 Life Sciences

Computational Deglutition
Ervin Sejdić, Georgia A. Malandraki,
and James L. Coyle

147 Applications Corner

Autonomous Unmanned Aerial Vehicles
Filming in Dynamic Unstructured Outdoor
Environments
Ioannis Mademlis, Nikos Nikolaidis,
Anastasios Tefas, Ioannis Pitas,
Tilman Wagner, and Alberto Messina

154 Lecture Notes

Paraconsistent Feature Engineering
Rodrigo Capobianco Guido

159 Tips & Tricks

Efficient Floating-Point Division for Digital
Signal Processing Application
Leonid Moroz and Volodymyr Samotyy

164 SP Competitions

Lung Cancer Radiomics
Arash Mohammadi, Parnian Afshar,
Amir Asif, Keyvan Farahani,
Justin Kirby, Anastasia Oikonomou,
and Konstantinos N. Plataniotis

DEPARTMENTS

3 From the Editor

Vehicular Applications of Signal Processing
Robert W. Heath, Jr.

4 President's Message

Dynamite, Electricity, and Nobel's World
Ali H. Sayed

174 Dates Ahead

176 Humor

Machine-Learning Billboard Collection
Robert W. Heath, Jr. and
Nuria González-Prelcic



PG. 174

The 26th IEEE International Conference on Image Processing will be held at the Taipei International Convention Center, Taipei, Taiwan, 22–25 September 2019.



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 University of Texas
at Austin, 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

Roberto Togneri—The University of Western
Australia

e-Newsletter

Ervin Sejdić—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.

EDITORIAL BOARD

Daniel Bliss—Arizona State University, USA

Danijela Cabric—University of California,
Los Angeles

Volkan Cevher—École polytechnique fédérale de
Lausanne, Switzerland

Mrityunjoy Chakraborty—Indian Institute of
Technology, Kharagpur, India

George Christos—Qualcomm, Inc., U.S.A.

Elza Erkip—New York University, U.S.A.

Alfonso Farina—Leonardo S.p.A., Italy

Clem Karl—Boston University, U.S.A.

C.-C. Jay Kuo—University of Southern California,
U.S.A.

Erik Larsson—Linköping University, Sweden

David Love—Purdue University, USA

Maria G. Martini—Kingston University, U.K.

Helen Meng—City University of Hong Kong,
Hong Kong SAR of China

Meinard Mueller—Friedrich-Alexander Universität
Erlangen-Nürnberg, Germany

Alejandro Ribeiro—University of Pennsylvania,
U.S.A.

Douglas O'Shaughnessy—INRS Université de
Recherche, Canada

Oswaldo Simeone—Kings College London, U.K.

Milica Stojanovic—Northeastern University, USA

Ananthram Swami, Army Research Labs, U.S.A.

Jong Chul Ye—KAIST, South Korea

Qing Zhao—Cornell University, USA

Josiane Zerubia—INRIA Sophia-Antipolis
Mediterranee, France

ASSOCIATE EDITORS—COLUMNS AND FORUM

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.

Rodrigo Capobianco Guido—São Paulo
State University, Brazil

Yuan-Hao Huang—National Tsing Hua University,
Taiwan

Euee Seon Jang—Hanyang University,
Republic of Korea

Vishal 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

Csaba Benedek—Hungarian Academy
of Sciences, Hungary

Yuhong Liu—Penn State University at Altoona,
U.S.A.

Andreas Merentitis—University of Athens,
Greece

Michael Muma—TU Darmstadt, Germany

Le Yang—Harbin Institute of Technology, China

Xiaorong Zhang—San Francisco State University,
U.S.A.

ASSOCIATE EDITOR—SOCIAL MEDIA/OUTREACH

Guijin Wang—Tsinghua University, China

IEEE SIGNAL PROCESSING SOCIETY

Ali H. Sayed—President

Ahmed Tewfik—President-Elect

Fernando Pereira—Vice President,
Conferences

Nikos D. Sidiropoulos—Vice President,
Membership

Sergio Theodoridis—Vice President, Publications

Walter Kellerman—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.2018.2877380

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.