

Editorial

Gian Luca Foresti

*Department of Mathematics and Computer Science (DIMI), University of Udine, 33100 Udine, Italy
Email: foresti@dimi.uniud.it*

Giovanni Ramponi

*Department of Electrical, Electronic, and Computer Engineering (DEEI), University of Trieste, 34127 Trieste, Italy
Email: ramponi@univ.trieste.it*

Carlo Regazzoni

*Department of Biophysical and Electronic Engineering (DIBE), University of Genoa, 16145 Genoa, Italy
Email: carlo@dibe.unige.it*

Giovanni L. Sicuranza

*Department of Electrical, Electronic, and Computer Engineering (DEEI), University of Trieste, 34127 Trieste, Italy
Email: sicuranza@univ.trieste.it*

Gianni Vernazza

*Department of Biophysical and Electronic Engineering (DIBE), University of Genoa, 16145 Genoa, Italy
Email: vernazza@dibe.unige.it*

The interest in nonlinear methods in signal processing is steadily increasing, also thanks to the advances in computational capacities that make it possible to implement sophisticated nonlinear processing techniques which in turn allow remarkable improvements with respect to standard and well-consolidated linear processing approaches. The vitality of the field is proved by the success of the Workshop on Nonlinear Signal and Image Processing (NSIP) organized every two years by the NSIP Board (<http://poseidon.csd.auth.gr/NSIP>) with the technical sponsorship of IEEE and EURASIP. The sixth NSIP Workshop was held in Grado, Italy, on June 2003. The main workshop topics were nonlinear theory and tools, nonlinear processing applications, and implementation of nonlinear systems. More than 100 papers selected from submissions received by researchers working in 24 countries were presented in oral and poster sessions. The participants in the workshop have been encouraged to expand their conference contributions into full papers for submission to this special issue of the EURASIP Journal on Applied Signal Processing. The answer to this solicitation has been enthusiastic and more than 60 papers have been received in response of the EURASIP JASP Call for Papers. In consideration of the high quality of the submitted manuscripts, the accepted papers have been subdivided in two Special Issues, the first

one including 17 papers while the second issue is presently in preparation.

This first special issue features papers covering topics that include theoretical contributions as well as application-oriented papers.

The first paper deals with a topic of general theoretical interest, that is, least absolute deviation (LAD) regression. LAD is a relevant tool for various applications of sciences and engineering, mainly due to its intrinsic robustness. In their paper, Li and Arce show that the optimization needed to solve the LAD regression problem can be viewed as a sequence of maximum likelihood estimates of location on the sample set. The authors derive an iterative solution where the concept of maximum likelihood is applied jointly with coordinate transformations and weighted median operations. They also show that the proposed method is comparable with the best algorithms available to date in terms of computational complexity, and has a greater potential to be implemented in hardware.

Another paper including a contribution of theoretical interest is the one by Cohen and Galleani. In this paper, modeling of time-frequency distributions is considered by proposing a nonlinear mapping from differential equations implicitly describing time-frequency transforms into a phase

space. The main advantage of the proposed mapping is the improved insight into the nature of the time-frequency model as well as the availability of approximated solution tools allowed by the representation in the phase space. The mapping is shown to be possible thanks to the use of bilinear transformations; general properties of bilinear transformations are briefly summarized and their application is described to the desired mapping. Finally, examples of application of the mapping process to some time-frequency distributions, such as the Wigner, Rihaczek, and smoothed pseudo-Wigner distribution are shown. This work opens a new theoretical way to evaluate the choice of time-frequency distributions for describing specific dynamic system models.

An application of the time-frequency analysis is presented in the paper by Gandetto, Guainazzo, and Regazzoni, where nonlinear signal processing techniques are used to realize a component of a software radio-based wireless terminal. The aim is to identify the presence of two communication modes, that is, bluetooth personal area network (based on a frequency-hopping air interface), and IEEE WLAN 802.11b (based on direct-sequence code-division multiple access). The mode identification procedure employs a time-frequency analysis to extract the main features of the two standards. Then, the classification ability of a Bayes classifier, of a back-propagation neural network, and of a support vector machine are analyzed. Results are given for an indoor environment in terms of probability of correct classification.

The instantaneous frequency estimation is the topic dealt with in the fourth paper, authored by Chandra Sekhar and Sreenivas. In this paper, the authors address the problem of estimating the instantaneous frequency (IF) of a real-valued phase signal. They propose an algorithm to estimate non-polynomial IF by local approximation, using a low-order polynomial, over a short segment of the signal. This involves the choice of window width to minimize the mean square error (MSE). It is shown how the optimal window width found minimizing the MSE is a function of the higher-order derivatives of the IF which are not available a priori. To overcome this problem, the authors propose an optimum solution, formulated using a data-adaptive window based on the concept of intersection of confidence intervals. The adaptive algorithm does not require a priori knowledge about IF. Simulation results show that the adaptive window-based method is superior to fixed window methods and is also better than adaptive spectrogram and adaptive Wigner-Ville distribution-based IF estimators for various signal-to-noise ratios.

The next four papers cover different aspects of system modeling using Volterra filters.

The paper by Pirani, Orcioni, and Turchetti deals with the classical problem of the kernel estimation of a discrete Volterra-Wiener system. It is well known that the estimation of the diagonal elements of such a model deserves particular attention. In fact, the estimation process of the kernel elements having at least two equal coordinates is affected by a high estimation error variance. In this paper, the authors propose a set of formulas for the identification of n th-order

Wiener kernels in the case of white Gaussian inputs, which limit such identification errors. Moreover, while the examples found in the literature often do not exceed the third order, it is shown in the paper that the proposed formulas constitute an efficient tool for the automatic generation of the algorithmic code allowing the identification of even higher-order kernels.

While in linear system identification, optimal excitation sequences have been found using the Cramer-Rao bound, this problem has not been thoroughly studied in the nonlinear case. In the paper by Koepl, Kubin, Paoli, and Josan, the Cramer-Rao bound for a factorizable Volterra model is derived so that further insights on optimal excitation sequences for the identification of nonlinear systems can be gained. Since the application motivating this study is adaptive nonlinear filtering for asymmetric digital subscriber loop (ADSL) circuits, the class of discrete multitone signals used in ADSL data transmission is especially considered.

In a communication system, most of the nonlinearities are usually attributed to the power amplifier (PA) present in the final stage of the transmitter chain. As a consequence, the prediction of the amount of spectral regrowth for a given level of PA nonlinearity is of great interest. In fact, since more linear PAs are less efficient, it is convenient to maximize the nonlinearity, and hence optimize the efficiency, subject to the spectral regrowth analysis of the nonlinear output. The aim of the paper by Tong Zhou and Raviv Raich is to derive for both memoryless and memory baseband PA models closed-form expressions for the output power spectral density. The PA models are based on the Taylor series, in the memoryless case, and on the discrete Volterra series in the case with memory. The input signals are assumed to be Gaussian distributed, as it happens with OFDM and forward link CDMA signals or signals at the satellite-borne relay.

The fourth paper in this group, authored by Carini and Sicuranza, is focused on the use of adaptive Volterra filters as nonlinear active noise controllers. In particular, they present a pair of new filtered-X affine projection (AP) algorithms derived from the simplified Volterra filter model of a homogeneous quadratic filter. By using the form of multichannel filter banks, Carini and Sicuranza demonstrate in the paper that the proposed AP filters show better convergence and tracking capabilities than the classical LSM and NLSM algorithms usually applied in nonlinear active noise controllers. Several computer simulations are presented for typical nonlinear situations.

The great interest in nonlinear methods in image processing tasks is documented by the following seven papers, dealing with image enhancement, noise removal, image reproduction, image quality evaluation, and pattern recognition.

In the paper by Battiato, Bosco, Castorina, and Messina, an automatic image enhancement technique based on feature-extraction methods is presented. This method has been designed to solve some of the typical drawbacks featured by mobile sensors and handset devices acquisition systems (mobile phones, PDA, etc.) due to poor optics, absence of flashgun, difficult scene-lighting conditions, and so forth.

The proposed method, after identifying in the captured images some visually significant features like skin characteristics, permits the selection, the enhancement, and/or tracking of regions of interest (e.g., faces). If no skin is present in the scene, the algorithm switches automatically to other features (such as contrast and focus). The limited overall computation time required by the proposed algorithm allows its use in real-time applications.

A novel technique for the enhancement of noisy images is presented by Russo. The proposed system adopts a simple piecewise linear function to combine the smoothing and sharpening effects that can easily be controlled by varying two parameters only. The quality of the enhanced image is then improved by introducing a further processing step for the cancellation of possible outliers still remaining in the image. Different computer simulations are presented showing that the proposed sharpening system is simple and effective. Experimental results contain also the application of the method to contrast enhancement of color images.

Human and computer vision systems currently use color information to sense the environment. The correct perception of color can help typical tasks, such as image understanding and object recognition. Unfortunately, noise and other impairments may significantly degrade the perceptual quality and the fidelity of the images so that the performance of the whole system can be negatively affected. Therefore, noise filtering is an essential part of any image processing task. The paper by Lukac, Plataniotis, Smolka, and Venetsanopoulos introduces a class of nonlinear multichannel filters able to remove impulsive noise in color images. The paper focuses on the so-called selection weighted vector filters, whose output is selected from an input set associated with the positive weight vector. The design characteristics are discussed in detail and the proposed filtering structures are carefully analyzed and tested on a variety of noise-corrupted test images.

In the paper by Shahidi, Moloney, and Ramponi, a new halftoning algorithm is analyzed (i.e., farthest-point halftoning) starting from a preliminary version of the same algorithm presented at NSIP. In the present paper, a novel dispersion measure is defined to improve the simplicity and flexibility of the result. This new stochastic screen algorithm is loosely based on Kang's dispersed-dot ordered dither halftone array construction technique, used as part of his microcluster halftoning method. The new halftoning algorithm proposed by the authors uses pixelwise measures of dispersion based on the one proposed by Kang, which is here modified to be more effective. In addition, their method exploits the concept of farthest-point sampling (FPS), introduced as a progressive irregular sampling, but uses a more efficient construction of the dot profiles. The proposed technique is compared with other state-of-the-art dither-based halftoning methods in both qualitative and quantitative manners.

In the paper by Costa, De Natale, and Granelli, an analysis of the effects of lossy compression algorithms applied to images affected by geometrical distortion is presented. The authors show that the encoding-decoding process results in a nonhomogeneous image degradation in the geometrically

corrected image, due to the different amount of information associated with each pixel. A distortion metric to quantify this aspect, called quadtree distortion map (QDM), is presented. QDM is exploited to achieve adaptive compression of geometrically distorted pictures, in order to ensure a uniform quality on final images. The authors present tests performed using JPEG and JPEG2000 coding standards in order to quantitatively and qualitatively assess the performance of the proposed method.

This group of papers finally includes two contributions addressing the issue of real-time implementations.

In the first one, Lohweg, Diederichs, and Mueller propose a combined method for pattern recognition and classification relying on a class of discrete nonlinear translation-invariant circular transforms and on a modified fuzzy pattern classification scheme. The algorithms are implemented in a field-programmable gate array (FPGA) operating at 40 MHz, whose features, implementation issues, and timing properties are surveyed. A new concept related to fast transforms as well as a modified fuzzy pattern classifier are described, together with various experimental results regarding the separability properties of different circular transforms in the case of binary patterns. Two possible applications are suggested, namely, the inspection of printed images and the recognition of handwritten characters. The system, once trained, is able to operate in real time.

In the second hardware-oriented contribution, a method for noise reduction able to improve the visual quality of the images in a video stream is presented. While the algorithms proposed in the literature often presume a software realization typically implemented on commercial DSPs, in the paper by Saponara, Fanucci, and Terreni, a VLSI architecture implemented in CMOS technology is presented. The advantage offered by this hardware realization essentially consists in the reduction of the power consumption. Therefore, it is a convenient solution for battery-powered video applications, such as wireless cameras, 3G mobile phones, personal digital assistants, and so on. The proposed structure is based on a nonlinear adaptive algorithm enhanced by a noise estimator for blind and dynamic adaptation to the input characteristics. The circuit is designed using a standard-cell library and minimizes the power consumption while allowing the real-time processing of the main video formats.

The last two papers in this special issue are still related to the processing of video signals.

In particular, in the paper authored by Feideropoulou and Pesquet-Popescu, the problem of the spatio-temporal decomposition of video sequences is considered. The proposed approach extends a stochastic model of hierarchical spatial and temporal dependencies between wavelet coefficients of still images to motion-compensated $2D + t$ decompositions. Such an extension implies taking into account additional dependencies and assuming the conditional probability law of the coefficients in a given spatiotemporal subband to be Gaussian with variance depending on the set of the spatiotemporal neighbors. Based on this new model, new estimators showing improved statistical performances have been proposed. Experimental results present an optimal

mean square predictor for missing coefficients which has been tested in two different applications of packet transmission.

Finally, the problem of boundary detection in presence of smooth transitions is considered by Guimarães, Leite, Coupric, and Araujo. The application which the authors address is the detection of gradual shot changes in video, such as a fade or a dissolve. The approach proposed is to create a single image which represents the “visual rhythms” of the sequence, with sharpened transitions, and to detect patterns in such an image. Comparative experiments are performed, and suitable quality parameters are defined, such as recall, precision, and error rate. The results show that the method is independent of the duration of the fade; its computational cost is moderate thanks to the 3D-to-2D mapping of the problem, even if a motion compensation preprocessing may be necessary.

The editors would like to thank all the authors for submitting their valuable contributions to this special issue and the referees for their prompt replies that allowed the timely publication of this issue. We hope that the EURASIP JASP readers may appreciate the extensive coverage of theories, methods, and applications, which demonstrate the applicability and effectiveness of nonlinear techniques in signal processing. Finally, we are pleased to remind the readers that the next appointment for the researchers working in this field is fixed at the next workshop in the series to be held in Sapporo, Japan, in May 2005. The rapid evolution of nonlinear signal processing lets us foresee that exciting new discoveries and original solutions for demanding tasks will be presented at NSIP-05. We look forward to seeing all of you in Sapporo in 2005!

Gian Luca Foresti
Giovanni Ramponi
Carlo Regazzoni
Giovanni L. Sicuranza
Gianni Vernazza

Gian Luca Foresti received the Laurea degree cum laude in electronic engineering and the Ph.D. degree in computer science from University of Genoa, Italy, in 1990 and in 1994, respectively. Since 2000 he is Professor of computer science at the Department of Mathematics and Computer Science (DIMI), University of Udine, where he is also Director of the Artificial Vision and Real-Time Systems (AVIRES) Lab. His main interests involve computer vision and image processing, multisensor data fusion, artificial neural networks, and pattern recognition. Professor Foresti is author or coauthor of more than 150 papers published in international journals and refereed international conferences. He is coauthor of the books *Multimedia Systems for Visual-based Surveillance* (Kluwer, 2000) and *Multisensor Surveillance Systems: The Fusion Perspective* (Kluwer, 2003). Recently he has been Guest Editor of a special issue of the *Proceedings of IEEE* on “Video Communications, Processing, and Understanding for Third Generation Surveillance Systems.” Currently, he is Guest Editor of



a special issue of the *IEEE Transactions on Systems, Man and Cybernetics* on “Ambient Intelligence.” He serves as a Reviewer for several international journals, and for the European Union in different research programs (MAST III, Long Term Research, and Brite-CRAFT). He is Senior Member of IEEE and member of IAPR.

Giovanni Ramponi was born in Trieste, Italy, in 1956. He received the degree in electronic engineering (summa cum laude) in 1981; he has been Researcher, then Associate Professor, and since 2000 he is Full Professor of Electronics at the Department of Electronics of the University of Trieste. His research interests include nonlinear digital signal processing, enhancement and feature extraction in images and image sequences, and image compression. He is the coinventor of various pending international patents and has published more than 120 papers in international journals, conference proceedings, and book chapters. Professor Ramponi was an Associate Editor of the *IEEE Signal Processing Letters* and is presently an Associate Editor of the *IEEE Transactions on Image Processing* and of the *SPIE Journal of Electronic Imaging*. He was Chairman of the Technical Programme of NSIP-03 and of Eusipco-96. He has been the local representative responsible for various scientific activities and contracts, both of the EU (LTR, ESPRIT, TMR) and national (CNR, MIUR), and has participated in other European and national research projects.



Carlo Regazzoni is Associate Professor in Telecommunications at the Department of Biophysical and Electronic Engineering (DIBE) of the University of Genoa since 1990. He obtained the Laurea degree and the Ph.D. in telecommunications and signal processing in 1987 and in 1992, respectively. He is Member of the CNIT Research Unit of Genoa and responsible for the Signal Processing and Telecommunications Group at DIBE. He has been scientifically and technically responsible for the R&D activities related to various EU projects, for DIBE participation in several Italian MIUR and CNR projects, as well as for industrial research contracts. His main research interests concern video sequence processing and understanding, software radio communications, and data fusion and multimodal localization. Professor Regazzoni has served as coeditor of four Kluwer books in Video Surveillance and Guest Editor of four special issues on the same topic in international journals (*The Proceedings of the IEEE*, *IEEE Signal Processing Magazine*, and *Real Time Imaging*). He has chaired special sessions at international conferences (ICIAP, EUSIPCO) and he has organized three international workshops in this research field (AVSS 1998, 2001, 2003). He is author or coauthor of more than 50 papers in international scientific journals.



Giovanni L. Sicuranza is a Professor of signal and image processing and the Head of the Image Processing Laboratory at DEEL, University of Trieste (Italy). His research interests include multidimensional digital filters, polynomial filters, processing of images and image sequences, image coding, and adaptive algorithms for echo cancellation and active noise control. He has published a number of papers in international journals and conference proceedings. He contributed to chapters for



six books and is the coeditor with Professor Sanjit Mitra, University of California at Santa Barbara, of the books *Multidimensional Processing of Video Signals* (Kluwer Academic Publisher, 1992) and *Nonlinear Image Processing* (Academic Press, 2001). He is the coauthor with Professor V. John Mathews, University of Utah at Salt Lake City, of the book *Polynomial Signal Processing* (J. Wiley, 2000). Professor Sicuranza has been a Member of the technical committees of numerous international conferences and the Chairman of EUSIPCO-96 and NSIP-03. He is an Associate Editor of "Multidimensional Systems and Signal Processing" and a Member of the Editorial Board of "Signal Processing" and "IEEE Signal Processing Magazine." Professor Sicuranza is currently the Awards Chairman of the Administrative Committee of EURASIP and a Member of the IMDSP Technical Committee of the IEEE Signal Processing Society. He has been one of the founders and the first Chairman of the Nonlinear Signal and Image Processing (NSIP) Board of which he is still a Member.

Gianni Vernazza was born in Genoa, Italy in 1945. He received the Laurea degree in electronic engineering from University of Genoa, Italy, in 1970. Since 1994, he is Full Professor of Telecommunication, and since 2002 he is Dean of the Faculty of Engineering at the University of Genoa. His main interests involve signal processing, pattern recognition, and image classification. He has considered different applicative fields,



such as biomedical images, remote sensing and land use classification, industrial imaging, intelligent surveillance, and nondestructive test. Professor Vernazza is author or coauthor of more than 200 papers published in international journals and refereed international conferences. He has been co-General Chairman of the 8th International Conference on Image Applications and Processing in 1995 and he is presently General Chairman of the International Conference on Image Processing (ICIP' 05), September 14–16, 2005 Genoa, Italy. He is Associate Editor of the International Journal on SMART Engineering System Design and he is Associate Editor of the International Journal of Pattern Recognition and Artificial Intelligence. He serves as a Reviewer for several international journals, and for the European Union in different research programs. He is Senior Member of IEEE, Member of IAPR, and Member of AEI.