

ISSN 1726-5479

SENSORS & TRANSDUCERS

8^{vol. 143}
/12



Sensors and Transducers Applications

International Frequency Sensor Association Publishing



Editors-in-Chief: professor Sergey Y. Yurish, tel.: +34 696067716, e-mail: editor@sensorsportal.com

Editors for Western Europe

Meijer, Gerard C.M., Delft University of Technology, The Netherlands
Ferrari, Vittorio, Università di Brescia, Italy

Editors for North America

Datskos, Panos G., Oak Ridge National Laboratory, USA
Fabien, J. Josse, Marquette University, USA
Katz, Evgeny, Clarkson University, USA

Editor South America

Costa-Felix, Rodrigo, Inmetro, Brazil

Editor for Eastern Europe

Sachenko, Anatoly, Ternopil State Economic University, Ukraine

Editor for Asia

Ohyama, Shinji, Tokyo Institute of Technology, Japan

Editor for Africa

Maki K.Habib, American University in Cairo, Egypt

Editor for Asia-Pacific

Mukhopadhyay, Subhas, Massey University, New Zealand

Editorial Advisory Board

Abdul Rahim, Ruzairi, Universiti Teknologi, Malaysia
Ahmad, Mohd Noor, Northern University of Engineering, Malaysia
Annamalai, Karthigeyan, National Institute of Advanced Industrial Science and Technology, Japan
Arcega, Francisco, University of Zaragoza, Spain
Arguel, Philippe, CNRS, France
Ahn, Jae-Pyoung, Korea Institute of Science and Technology, Korea
Arndt, Michael, Robert Bosch GmbH, Germany
Ascoli, Giorgio, George Mason University, USA
Atalay, Selcuk, Inonu University, Turkey
Atghiaee, Ahmad, University of Tehran, Iran
Augutis, Vyngantas, Kaunas University of Technology, Lithuania
Avachit, Patil Lalchand, North Maharashtra University, India
Ayesh, Aladdin, De Montfort University, UK
Azamimi, Azian binti Abdullah, Universiti Malaysia Perlis, Malaysia
Bahreyni, Behraad, University of Manitoba, Canada
Baliga, Shankar, B., General Motors Transnational, USA
Baoxian, Ye, Zhengzhou University, China
Barford, Lee, Agilent Laboratories, USA
Barlingay, Ravindra, RF Arrays Systems, India
Basu, Sukumar, Jadavpur University, India
Beck, Stephen, University of Sheffield, UK
Ben Bouzid, Sihem, Institut National de Recherche Scientifique, Tunisia
Benachaiba, Chellali, Université de Bechar, Algeria
Binnie, T. David, Napier University, UK
Bischoff, Gerlinde, Inst. Analytical Chemistry, Germany
Bodas, Dhananjay, IMTEK, Germany
Borges Carval, Nuno, Universidade de Aveiro, Portugal
Bouchikhi, Benachir, University Moulay Ismail, Morocco
Bousbia-Salah, Mounir, University of Annaba, Algeria
Bouvet, Marcel, CNRS – UPMC, France
Brudzewski, Kazimierz, Warsaw University of Technology, Poland
Cai, Chenxin, Nanjing Normal University, China
Cai, Qingyun, Hunan University, China
Calvo-Gallego, Jaime, Universidad de Salamanca, Spain
Campanella, Luigi, University La Sapienza, Italy
Carvalho, Vitor, Minho University, Portugal
Cecelja, Franjo, Brunel University, London, UK
Cerda Belmonte, Judith, Imperial College London, UK
Chakrabarty, Chandan Kumar, Universiti Tenaga Nasional, Malaysia
Chakravorty, Dipankar, Association for the Cultivation of Science, India
Changhai, Ru, Harbin Engineering University, China
Chaudhari, Gajanan, Shri Shivaji Science College, India
Chavali, Murthy, N.I. Center for Higher Education, (N.I. University), India
Chen, Jiming, Zhejiang University, China
Chen, Rongshun, National Tsing Hua University, Taiwan
Cheng, Kuo-Sheng, National Cheng Kung University, Taiwan
Chiang, Jeffrey (Cheng-Ta), Industrial Technol. Research Institute, Taiwan
Chiriac, Horia, National Institute of Research and Development, Romania
Chowdhuri, Arijit, University of Delhi, India
Chung, Wen-Yaw, Chung Yuan Christian University, Taiwan
Corres, Jesus, Universidad Publica de Navarra, Spain
Cortes, Camilo A., Universidad Nacional de Colombia, Colombia
Courtois, Christian, Université de Valenciennes, France
Cusano, Andrea, University of Sannio, Italy
D'Amico, Arnaldo, Università di Tor Vergata, Italy
De Stefano, Luca, Institute for Microelectronics and Microsystem, Italy
Deshmukh, Kiran, Shri Shivaji Mahavidyalaya, Barshi, India
Dickert, Franz L., Vienna University, Austria
Diegues, Angel, University of Barcelona, Spain
Dighavkar, C. G., M.G. Vidyamandir's L. V.H. College, India
Dimitropoulos, Panos, University of Thessaly, Greece
Ding, Jianning, Jiangsu Polytechnic University, China

Djordjevic, Alexandar, City University of Hong Kong, Hong Kong
Donato, Nicola, University of Messina, Italy
Donato, Patricio, Universidad de Mar del Plata, Argentina
Dong, Feng, Tianjin University, China
Driljaca, Predrag, Intersema Sensoric SA, Switzerland
Dubey, Venketesh, Bournemouth University, UK
Enderle, Stefan, Univ. of Ulm and KTB Mechatronics GmbH, Germany
Erdem, Gursan K. Arzum, Ege University, Turkey
Erkmen, Aydan M., Middle East Technical University, Turkey
Estelle, Patrice, Insa Rennes, France
Estrada, Horacio, University of North Carolina, USA
Faiz, Adil, INSA Lyon, France
Fericean, Sorin, Balluff GmbH, Germany
Fernandes, Joana M., University of Porto, Portugal
Francioso, Luca, CNR-IMM Institute for Microelectronics and Microsystems, Italy
Francis, Laurent, University Catholique de Louvain, Belgium
Fu, Weiling, South-Western Hospital, Chongqing, China
Gaura, Elena, Coventry University, UK
Geng, Yanfeng, China University of Petroleum, China
Gole, James, Georgia Institute of Technology, USA
Gong, Hao, National University of Singapore, Singapore
Gonzalez de la Rosa, Juan Jose, University of Cadiz, Spain
Grael, Annette, Goteborg University, Sweden
Graff, Mason, The University of Texas at Arlington, USA
Guan, Shan, Eastman Kodak, USA
Guillet, Bruno, University of Caen, France
Guo, Zhen, New Jersey Institute of Technology, USA
Gupta, Narendra Kumar, Napier University, UK
Hadjiloucas, Sillas, The University of Reading, UK
Haider, Mohammad R., Sonoma State University, USA
Hashsham, Syed, Michigan State University, USA
Hasni, Abdelhafid, Bechar University, Algeria
Hernandez, Alvaro, University of Alcalá, Spain
Hernandez, Wilmar, Universidad Politecnica de Madrid, Spain
Homentcovschi, Dorel, SUNY Binghamton, USA
Horstman, Tom, U.S. Automation Group, LLC, USA
Hsiai, Tzung (John), University of Southern California, USA
Huang, Jeng-Sheng, Chung Yuan Christian University, Taiwan
Huang, Star, National Tsing Hua University, Taiwan
Huang, Wei, PSG Design Center, USA
Hui, David, University of New Orleans, USA
Jaffrezic-Renault, Nicole, Ecole Centrale de Lyon, France
James, Daniel, Griffith University, Australia
Janting, Jakob, DELTA Danish Electronics, Denmark
Jiang, Liudi, University of Southampton, UK
Jiang, Wei, University of Virginia, USA
Jiao, Zheng, Shanghai University, China
John, Joachim, IMEC, Belgium
Kalach, Andrew, Voronezh Institute of Ministry of Interior, Russia
Kang, Moonho, Sunmoon University, Korea South
Kaniusas, Eugenijus, Vienna University of Technology, Austria
Katake, Anup, Texas A&M University, USA
Kausel, Wilfried, University of Music, Vienna, Austria
Kavasoglu, Nese, Mugla University, Turkey
Ke, Cathy, Tyndall National Institute, Ireland
Khelfaoui, Rachid, Université de Bechar, Algeria
Khan, Asif, Aligarh Muslim University, Aligarh, India
Kim, Min Young, Kyungpook National University, Korea South
Ko, Sang Choon, Electronics. and Telecom. Research Inst., Korea South
Kotulski, Malgorzata, Wroclaw University of Technology, Poland
Kockar, Hakan, Balikesir University, Turkey
Kong, Ing, RMIT University, Australia
Kratz, Henrik, Uppsala University, Sweden

Krishnamoorthy, Ganesh, University of Texas at Austin, USA
Kumar, Arun, University of Delaware, Newark, USA
Kumar, Subodh, National Physical Laboratory, India
Kung, Chih-Hsien, Chang-Jung Christian University, Taiwan
Lacnjevac, Caslav, University of Belgrade, Serbia
Lay-Ekuakille, Aime, University of Lecce, Italy
Lee, Jang Myung, Pusan National University, Korea South
Lee, Jun Su, Amkor Technology, Inc. South Korea
Lei, Hua, National Starch and Chemical Company, USA
Li, Fengyuan (Thomas), Purdue University, USA
Li, Genxi, Nanjing University, China
Li, Hui, Shanghai Jiaotong University, China
Li, Sihua, Agiltron, Inc., USA
Li, Xian-Fang, Central South University, China
Li, Yuefa, Wayne State University, USA
Liang, Yuanchang, University of Washington, USA
Liawruangrath, Saisunee, Chiang Mai University, Thailand
Liew, Kim Meow, City University of Hong Kong, Hong Kong
Lin, Hermann, National Kaohsiung University, Taiwan
Lin, Paul, Cleveland State University, USA
Linderholm, Pontus, EPFL - Microsystems Laboratory, Switzerland
Liu, Aihua, University of Oklahoma, USA
Liu Changgeng, Louisiana State University, USA
Liu, Cheng-Hsien, National Tsing Hua University, Taiwan
Liu, Songqin, Southeast University, China
Lodeiro, Carlos, University of Vigo, Spain
Lorenzo, Maria Encarnacio, Universidad Autonoma de Madrid, Spain
Lukaszewicz, Jerzy Pawel, Nicholas Copernicus University, Poland
Ma, Zhanfang, Northeast Normal University, China
Majstorovic, Vidosav, University of Belgrade, Serbia
Malyshev, V.V., National Research Centre 'Kurchatov Institute', Russia
Marquez, Alfredo, Centro de Investigacion en Materiales Avanzados, Mexico
Matay, Ladislav, Slovak Academy of Sciences, Slovakia
Mathur, Prafull, National Physical Laboratory, India
Maurya, D.K., Institute of Materials Research and Engineering, Singapore
Mekid, Samir, University of Manchester, UK
Melnyk, Ivan, Photon Control Inc., Canada
Mendes, Paulo, University of Minho, Portugal
Mennell, Julie, Northumbria University, UK
Mi, Bin, Boston Scientific Corporation, USA
Minas, Graca, University of Minho, Portugal
Mishra, Vivekanand, National Institute of Technology, India
Moghavvemi, Mahmoud, University of Malaya, Malaysia
Mohammadi, Mohammad-Reza, University of Cambridge, UK
Molina Flores, Esteban, Benemérita Universidad Autónoma de Puebla, Mexico
Moradi, Majid, University of Kerman, Iran
Morello, Rosario, University "Mediterranea" of Reggio Calabria, Italy
Mounir, Ben Ali, University of Sousse, Tunisia
Mrad, Nezhil, Defence R&D, Canada
Mulla, Imtiaz Sirajuddin, National Chemical Laboratory, Pune, India
Nabok, Aleksey, Sheffield Hallam University, UK
Neelamegam, Periasamy, Sastra Deemed University, India
Neshkova, Milka, Bulgarian Academy of Sciences, Bulgaria
Oberhammer, Joachim, Royal Institute of Technology, Sweden
Ould Lahoucine, Cherif, University of Guelma, Algeria
Pamidighanta, Sayanu, Bharat Electronics Limited (BEL), India
Pan, Jisheng, Institute of Materials Research & Engineering, Singapore
Park, Joon-Shik, Korea Electronics Technology Institute, Korea South
Passaro, Vittorio M. N., Politecnico di Bari, Italy
Penza, Michele, ENEA C.R., Italy
Pereira, Jose Miguel, Instituto Politecnico de Seteбал, Portugal
Petsev, Dimiter, University of New Mexico, USA
Pogacnik, Lea, University of Ljubljana, Slovenia
Post, Michael, National Research Council, Canada
Prance, Robert, University of Sussex, UK
Prasad, Ambika, Gulbarga University, India
Prateepasen, Asa, Kingmoungut's University of Technology, Thailand
Pugno, Nicola M., Politecnico di Torino, Italy
Pullini, Daniele, Centro Ricerche FIAT, Italy
Pumera, Martin, National Institute for Materials Science, Japan
Radhakrishnan, S., National Chemical Laboratory, Pune, India
Rajanna, K., Indian Institute of Science, India
Ramadan, Qasem, Institute of Microelectronics, Singapore
Rao, Basuthkar, Tata Inst. of Fundamental Research, India
Raoof, Kosai, Joseph Fourier University of Grenoble, France
Rastogi Shiva, K., University of Idaho, USA
Reig, Candid, University of Valencia, Spain
Restivo, Maria Teresa, University of Porto, Portugal
Robert, Michel, University Henri Poincare, France
Rezazadeh, Ghader, Urmia University, Iran
Royo, Santiago, Universitat Politecnica de Catalunya, Spain
Rodriguez, Angel, Universidad Politecnica de Cataluna, Spain
Rothberg, Steve, Loughborough University, UK
Sadana, Ajit, University of Mississippi, USA
Sadeghian Marnani, Hamed, TU Delft, The Netherlands
Sapozhnikova, Ksenia, D.I.Mendeleyev Institute for Metrology, Russia
Sandacci, Serghei, Sensor Technology Ltd., UK
Saxena, Vibha, Bhabha Atomic Research Centre, Mumbai, India
Schneider, John K., Ultra-Scan Corporation, USA
Sengupta, Deepak, Advance Bio-Photonics, India
Seif, Selemeni, Alabama A & M University, USA
Seifter, Achim, Los Alamos National Laboratory, USA
Shah, Kriyang, La Trobe University, Australia
Sankarraj, Anand, Detector Electronics Corp., USA
Silva Girao, Pedro, Technical University of Lisbon, Portugal
Singh, V. R., National Physical Laboratory, India
Slomovitz, Daniel, UTE, Uruguay
Smith, Martin, Open University, UK
Soleimanpour, Amir Masoud, University of Toledo, USA
Soleymannpour, Ahmad, University of Toledo, USA
Somani, Prakash R., Centre for Materials for Electronics Technol., India
Sridharan, M., Sastra University, India
Srinivas, Talabattula, Indian Institute of Science, Bangalore, India
Srivastava, Arvind K., NanoSonix Inc., USA
Stefan-van Staden, Raluca-Ioana, University of Pretoria, South Africa
Stefanescu, Dan Mihai, Romanian Measurement Society, Romania
Sumriddetchka, Sarun, National Electronics and Comp. Technol. Center, Thailand
Sun, Chengliang, Polytechnic University, Hong-Kong
Sun, Dongming, Jilin University, China
Sun, Junhua, Beijing University of Aeronautics and Astronautics, China
Sun, Zhiqiang, Central South University, China
Suri, C. Raman, Institute of Microbial Technology, India
Sysoev, Victor, Saratov State Technical University, Russia
Szewczyk, Roman, Industr. Research Inst. for Automation and Measurement, Poland
Tan, Ooi Kiang, Nanyang Technological University, Singapore
Tang, Dianping, Southwest University, China
Tang, Jaw-Luen, National Chung Cheng University, Taiwan
Teker, Kasif, Frostburg State University, USA
Thirunavukkarasu, I., Manipal University Karnataka, India
Thumbavanam Pad, Kartik, Carnegie Mellon University, USA
Tian, Gui Yun, University of Newcastle, UK
Tsiantos, Vassilios, Technological Educational Institute of Kaval, Greece
Tsigara, Anna, National Hellenic Research Foundation, Greece
Twomey, Karen, University College Cork, Ireland
Valente, Antonio, University, Vila Real, - U.T.A.D., Portugal
Vanga, Raghav Rao, Summit Technology Services, Inc., USA
Vaseashta, Ashok, Marshall University, USA
Vazquez, Carmen, Carlos III University in Madrid, Spain
Vieira, Manuela, Instituto Superior de Engenharia de Lisboa, Portugal
Vigna, Benedetto, STMicroelectronics, Italy
Vrba, Radimir, Brno University of Technology, Czech Republic
Wandelt, Barbara, Technical University of Lodz, Poland
Wang, Jiangping, Xi'an Shiyong University, China
Wang, Kedong, Beihang University, China
Wang, Liang, Pacific Northwest National Laboratory, USA
Wang, Mi, University of Leeds, UK
Wang, Shinn-Fwu, Ching Yun University, Taiwan
Wang, Wei-Chih, University of Washington, USA
Wang, Wensheng, University of Pennsylvania, USA
Watson, Steven, Center for NanoSpace Technologies Inc., USA
Weiping, Yan, Dalian University of Technology, China
Wells, Stephen, Southern Company Services, USA
Wolkenberg, Andrzej, Institute of Electron Technology, Poland
Woods, R. Clive, Louisiana State University, USA
Wu, DerHo, National Pingtung Univ. of Science and Technology, Taiwan
Wu, Zhaoyang, Hunan University, China
Xiu Tao, Ge, Chuzhou University, China
Xu, Lisheng, The Chinese University of Hong Kong, Hong Kong
Xu, Sen, Drexel University, USA
Xu, Tao, University of California, Irvine, USA
Yang, Dongfang, National Research Council, Canada
Yang, Shuang-Hua, Loughborough University, UK
Yang, Wuqiang, The University of Manchester, UK
Yang, Xiaoling, University of Georgia, Athens, GA, USA
Yaping Dan, Harvard University, USA
Ymeti, Aurel, University of Twente, Netherlands
Yong Zhao, Northeastern University, China
Yu, Haihu, Wuhan University of Technology, China
Yuan, Yong, Massey University, New Zealand
Yufera Garcia, Alberto, Seville University, Spain
Zakaria, Zulkarnay, University Malaysia Perlis, Malaysia
Zagnoni, Michele, University of Southampton, UK
Zamani, Cyrus, Universitat de Barcelona, Spain
Zeni, Luigi, Second University of Naples, Italy
Zhang, Minglong, Shanghai University, China
Zhang, Quintao, University of California at Berkeley, USA
Zhang, Weiping, Shanghai Jiao Tong University, China
Zhang, Wenming, Shanghai Jiao Tong University, China
Zhang, Xueji, World Precision Instruments, Inc., USA
Zhong, Haoxiang, Henan Normal University, China
Zhu, Qing, Fujifilm Dimatix, Inc., USA
Zorzano, Luis, Universidad de La Rioja, Spain
Zourob, Mohammed, University of Cambridge, UK

Contents

Volume 143
Issue 8
August 2012

www.sensorsportal.com

ISSN 1726-5479

Research Articles

Research in Nanothermometry. Part 7. Ultrasonic Thermometer Based on Nanostructured Thermometric Substance, Bohdan Stadnyk, Svyatoslav Yatsyshyn, Yaroslav Lutsyk, Pylyp Skoropad, Zenoviy Kolodiy, Orysya Kozak	1
Plasma Polymerized Thin Film Sensor: Synthesis and Application K. A. Koparkar	10
Current Trend of Tactile Sensor in Advanced Applications Ruzairi Abdul Rahim , Mohamed Faisal Abdul Waduth, Haziq Izzuan Jaafar, Nor Muzakir Nor Ayob, Pei Ling Leow.....	32
Quartz Crystal Microbalance DNA Based Biosensor for Diagnosis: A Review Thongchai Kaewphinit, Somchai Santiwatanakul, and Kosum Chansiri.....	44
Review on Interaction between Electromagnetic Field and Biological Tissues Zulkarnay Zakaria, Abdul Rahim, Pick Yern Lee, Muhammad Saiful Badri Mansor, Azian Azamimi Abdullah, Sazali Yaacob, Siti Zarina Mohd. Muji.....	60
Force Measurement Using Magnetic Potentiometer Sunan Huang, Haoyong Yu.....	71
A New Method for Linear Compression and Decompression of Sequential Sensor Signals Zhiqiang Sun, Zhiyong Li.....	79
FPGA-Based Temperature Monitoring and Control System for Infant Incubator Bharathi Navaneethakrishnan, Neelamegam P.	88
Design and Simulation of a Novel MEMS Based Linear Actuator for Mirror Shape Correction Applications, Ehsan Atashzaban.....	98
Virtual Prototyping of a MEMS Capacitive Pressure Sensor for Tire Pressure Monitoring System Using Intellisuite, Anurekha Sharma, Munju Mittal, Deepika Saini.....	106
Low Cost of Preparation of Infrared PbS Detector Using Copper Electrodes of PCB Hariyadi Soetedjo, Gunawan S. Prabowo and Darsono	120
System Identification of MOS Gas Sensors and Stability Analysis Nimisha Dutta, Sumi Kankana Dewan and Manabendra Bhuyan.....	127
Tin Modified Tungsten Oxide Thin Film for Ammonia Gas Sensing at Room Temperature K. J. Patel, M. S. Desai, C. J. Panchal	136
Electrochemical Based Diagnosis of Ascorbic Acid Anjum Gahlaut, Ashish Gothwal, Anil K. Chhillar, Vikas Hooda	143
Resistive Type Moisture Sensor Based on WO₃ Nanomaterial Anupam Tripathi, Karunesh Tiwari, N. K. Pandey, Vidhu Tripathi	152

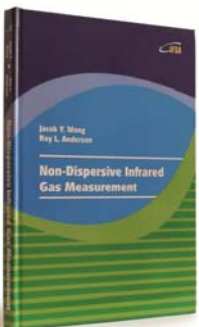
Authors are encouraged to submit article in MS Word (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com
Please visit journal's webpage with preparation instructions: <http://www.sensorsportal.com/HTML/DIGEST/Submission.htm>

International Frequency Sensor Association (IFSA).



International Frequency Sensor Association (IFSA) Publishing





Jacob Y. Wong, Roy L. Anderson
Non-Dispersive Infrared Gas Measurement

Written by experts in the field, the *Non-Dispersive Infrared Gas Measurement* begins with a brief survey of various gas measurement techniques and continues with fundamental aspects and cutting-edge progress in NDIR gas sensors in their historical development.

- It addresses various fields, including:
- Interactive and non-interactive gas sensors
- Non-dispersive infrared gas sensors' components
- Single- and Double beam designs
- Historical background and today's of NDIR gas measurements

Providing sufficient background information and details, the book *Non-Dispersive Infrared Gas Measurement* is an excellent resource for advanced level undergraduate and graduate students as well as researchers, instrumentation engineers, applied physicists, chemists, material scientists in gas, chemical, biological, and medical sensors to have a comprehensive understanding of the development of non-dispersive infrared gas sensors and the trends for the future investigation.

Formats: printable pdf (Acrobat) and print (hardcover), 120 pages
ISBN: 978-84-615-9732-1,
e-ISBN: 978-84-615-9512-9

http://sensorsportal.com/HTML/BOOKSTORE/NDIR_Gas_Measurement.htm



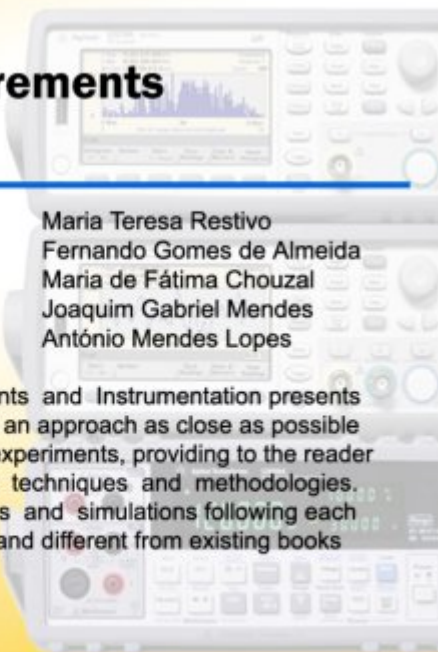
International Frequency Sensor Association Publishing



Handbook of Laboratory Measurements and Instrumentation

**Maria Teresa Restivo
Fernando Gomes de Almeida
Maria de Fátima Chouzal
Joaquim Gabriel Mendes
António Mendes Lopes**

The Handbook of Laboratory Measurements and Instrumentation presents experimental and laboratory activities with an approach as close as possible to reality, even offering remote access to experiments, providing to the reader an excellent tool for learning laboratory techniques and methodologies. Book includes dozens videos, animations and simulations following each of chapters. It makes the title very valued and different from existing books on measurements and instrumentation.



Order online:
http://www.sensorsportal.com/HTML/BOOKSTORE/Handbook_of_Measurements.htm

A New Method for Linear Compression and Decompression of Sequential Sensor Signals

^{1, 2,*} Zhiqiang SUN, ^{1,2} Zhiyong LI

¹ School of Energy Science and Engineering, Central South University, Changsha 410083, China

² Hunan Key Laboratory of Energy Conservation in Process Industry, Central South University, Changsha 410083, China

*E-mail: zqsun@csu.edu.cn

Received: 23 May 2012 / Accepted: 21 August 2012 / Published: 28 August 2012

Abstract: In this paper we bring forward a new linear method of lossy data compression aiming at effective and efficient utilization of sequential sensor signals. In the course of compression, the filtering and encapsulation are carried out first according to the signal type and the threshold value; second, the linear compression is conducted by comparing the maximum and minimum slopes of the sensor signal; third, the compressed signal is archived into the historical data storage zone for later use. Conversely, the signal is reconstructed by linear interpolation during the decompression process. The test results of a standard sinusoidal signal and a measured dynamic pressure signal show that the proposed method has higher compression ratio and less compression error than the spinning door transformation. It also reveals that this method is suitable for the compression and decompression of various types of sensor signals, especially for those containing massive data, multiple sampling, disturbance and redundancy. Copyright © 2012 IFSA.

Keywords: Sequential sensor signal, Lossy data compression, Linear interpolation, Compression ratio, Compression error.

1. Introduction

Accurate measurement and efficient utilization of sensor signals are of great importance to the process control in industry such as energy, power, metallurgy, etc. Sensor signals in process industry are usually sequential, massive, and high-frequency [1, 2]. Due to the huge amount of data, it has been one of the most difficult problems in practical applications to handle those signals in a real-time way. Thereby it is necessary to compress sensor signals to decrease storage space and speed up transmission efficiency.

Since sensor signals normally has time attribute, small-scale fluctuations hardly affect the history curve. Hence efficient compression of sensor signals can be achieved by lossy compression through discarding partial redundant data.

Investigations on the compression of sensor signals are intensive in recent years. Langen pointed out the importance and potential usage of sensor signals in nuclear power plants [3]. Hale and Sellers proposed the methods of box car and backward slope [4]. When processing the sensor signals with linear drifts and fluctuations, the compression ratio of box car was not satisfactory and the anti-noise ability was poor. Mah *et al* put forward a piecewise linear trending method, which could adjust the threshold value of compression errors automatically [5]. Gray conducted a systematical study on the method of vector quantization [6]. MacGregor and Kourti adopted the statistical method to achieve the compression of multivariable sensor signals [7]. Baksh and Stephanopoulos employed the wavelet method to extract time-domain characteristics and to discern process failure, and generalized the applications of wavelets to data compression in chemical industry [8–10]. Singha and Seborg analyzed the pattern matching problem in data compression, and concluded that the wavelet compression had the best pattern matching effect [12]. Imtiaz *et al* [12] compared the performance of spinning door transformation and wavelet in aspect of multivariate analysis, and concluded that the wavelet method is superior. However, both the vector and the wavelet methods need large amount of computation, thus requiring high-performance hardware to complete real-time data compression.

The purpose of this paper is to achieve effective and efficient utilization of sequential sensor signals by a new linear method of lossy data compression aim. As shown in Fig. 1, according to the signal type and the threshold value, the signal is filtered at the beginning of this method, then encapsulated and stored into a cache zone. When the cache zone is full, through comparing the maximum and minimum slopes, the encapsulated signal is compressed and finally archived into the historical data storage zone for later use. During the decompression process, the signal is reconstructed by linear interpolation of the data in the historical storage zone. This method is suitable for the compression and decompression of various types of sensor signals, especially for those containing massive data, multiple sampling, disturbance and redundancy.

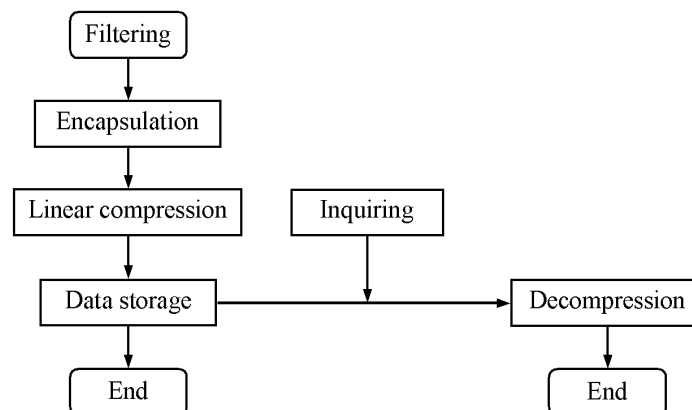


Fig. 1. Block diagram of the linear compression and decompression method proposed.

2. Linear Compression and Decompression

2.1. Preprocessing

The preprocessing of sensor signals includes the processes of filtering and encapsulation. Generally, the moving average algorithm is used to filter the signal. First of all, regard N sample values continuously obtained as a queue (the length of the queue is fixed as N), calculate the average value of this queue, put

the new data sampled each time to the tail of the queue and at the same time get rid of the data at the original head of the queue. Then calculate the arithmetic average value of the N data in the queue and get the filtered result. For the signals from a system with relative large delays, use the weighted recursive average algorithm to filter the signal, which applies different weight on the data at different time. The weight is normally larger for the data closer to the current time. After filtering, encapsulate the data that satisfy the time interval of compression. The data encapsulated all contains the components of time scale, data value, data characteristics, etc.

2.2. Linear Compression

The compression process of the method proposed is divided into four steps.

Step1: For a group of data to be compressed (x_i, y_i) ($i = 1, 2, \dots$), establish a straight line based on the first data (x_1, y_1) and the second data (x_2, y_2) plus the baseline compression threshold value $(0, t)$. The slope $k_{\max}$ of this straight line is regarded as the upper limit slope of the compression:

$$k_{\max} = \frac{(y_2 + t - y_1)}{(x_2 - x_1)}, \quad (1)$$

where x represents time, y is the data value at time x , and t is the threshold value of the compression.

Establish a second straight line based on the subtraction of the first data (x_1, y_1) and the second data (x_2, y_2) from the compression threshold value $(0, t)$. The slope $k_{\min}$ of this straight line is regarded as the lower limit slope of this compression:

$$k_{\min} = \frac{(y_2 - t - y_1)}{(x_2 - x_1)}. \quad (2)$$

Step 2: Repeat step 1 using the first and third data, and get the new slopes:

$$k'_{\max} = \frac{(y_3 + t - y_1)}{(x_3 - x_1)}, \quad (3)$$

$$k'_{\min} = \frac{(y_3 - t - y_1)}{(x_3 - x_1)}. \quad (4)$$

Define

$$k_{\max} = \min(k'_{\max}, k_{\max}), \quad (5)$$

$$k_{\min} = \max(k'_{\min}, k_{\min}). \quad (6)$$

Step 3: Compare the current values of $k_{\max}$ and $k_{\min}$. If $k_{\max}$ is greater than $k_{\min}$, then $i = i + 1$ and return to step 2; if $k_{\max}$ is less than or equal to $k_{\min}$, then the compression is terminated, document the current i as n , save the data (x_{n-1}, y_{n-1}) at the data point $n-1$ in the compression, and adjust the data value y_{n-1} at $n-1$ according to the average value of $k_{\max}$ and $k_{\min}$ at the data point $n-1$. We obtain:

$$y_{n-1} = \left(\frac{k_{\max} + k_{\min}}{2} \right) \cdot (x_{n-1} - x_1) + y_1. \quad (7)$$

Save the refreshed data (x_{n-1}, y_{n-1}) to the historical data storage zone as shown in Fig. 2.

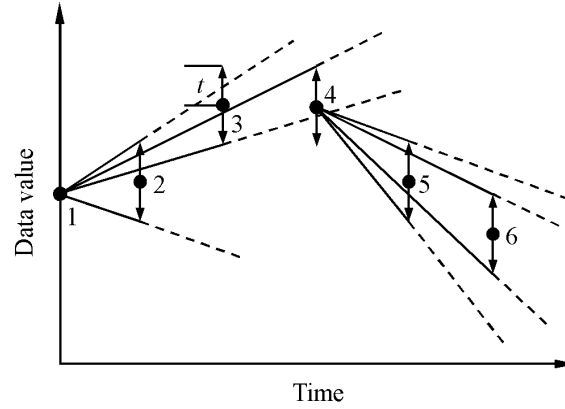


Fig. 2. Principle of linear compression process.

Step 4: Process the rest part of the data to be compressed till the last one. The specific procedure is: regard (x_n, y_n) at data point n as the first new data point, regard (x_{n+1}, y_{n+1}) at data point $n+1$ as the second new data point, repeat steps 1–3 till the last data, then the whole compression process is completed.

If the last data is reached during the compression, then save this data and terminate the compression. The linear compression process is shown in Fig. 3.

2.3. Decompression

During the decompression process, the data values at each time can be obtained through setting time step and linear interpolation according to the time step increment Δ_{inct} . The procedure of the decompression process is given in Fig. 4.

3. Compression Tests and Discussion

We use a standard sinusoidal signal and a measured dynamic pressure signal as original data to test the performance of the linear compression method proposed.

The standard sinusoidal signal contains totally 500 data points, and its period is 100 with amplitude of 10. Since the original data is a standard sinusoidal signal, it is not filtered herein. As seen in Fig. 5, when compression threshold values are set as 5 % and 1 %, the compression ratios by the linear compression method are 22.5:1 and 11.9:1. Note that the x-coordinate represents the data points, and the y-coordinate represents the data values.

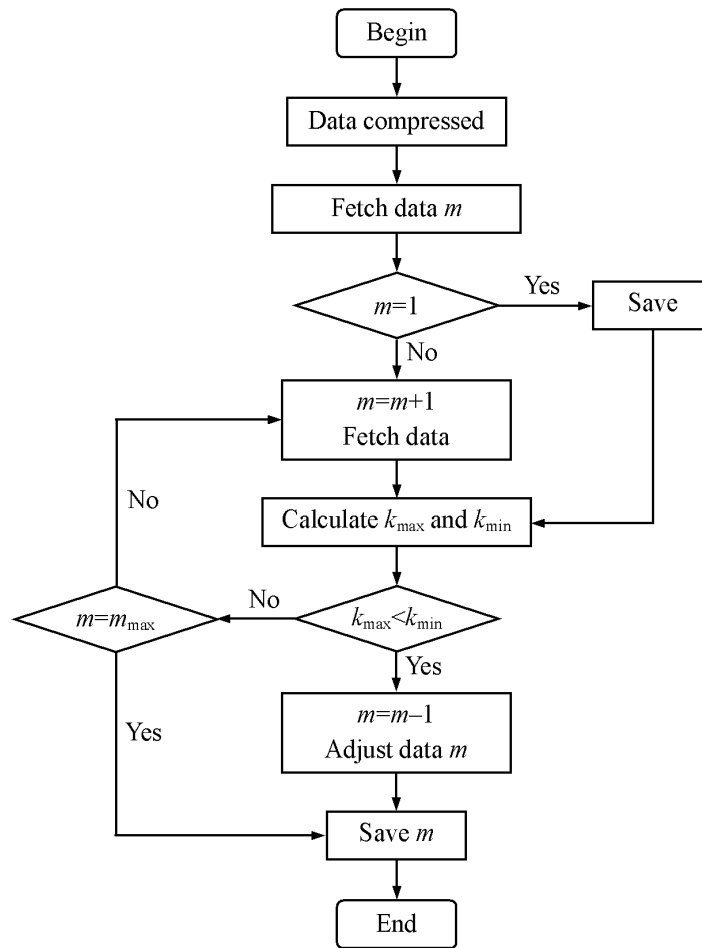


Fig. 3. Block diagram of linear compression process.

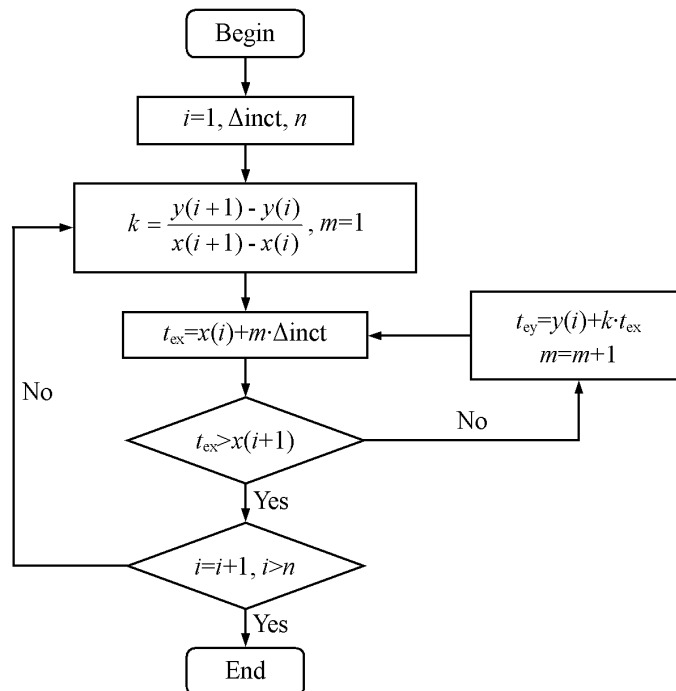


Fig. 4. Block diagram of decompression process.

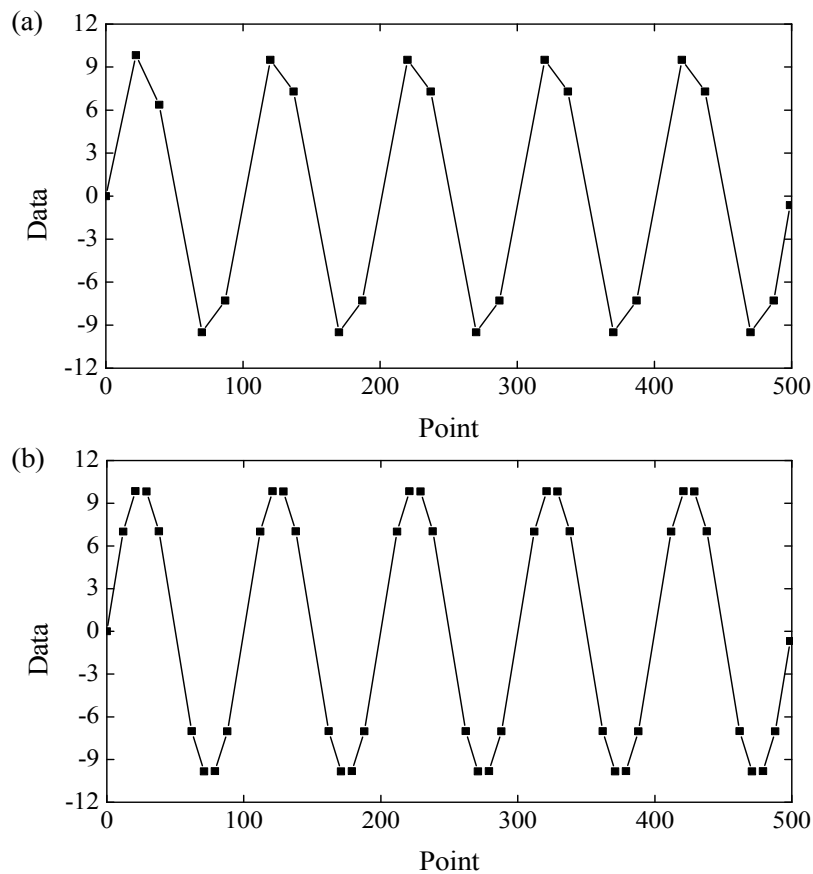


Fig. 5. Linear compression results of a standard sinusoidal signal: (a) Compression threshold value is 5%; (b) Compression threshold value is 1 %.

Fig. 6 gives the compression result of a standard sinusoidal signal by the spinning door transformation with a compression threshold value of 1%. Spinning door transformation is one of the most famous and efficient lossy compression algorithms in the field of process control. The spinning door transformation can only reach the compression ratio of 9.6:1. After decompression, compared with the original data, the average absolute error is 0.16 using the spinning door transformation; however, the average absolute error is 0.11 using the linear compression method proposed, which has a decrease of 31 %.

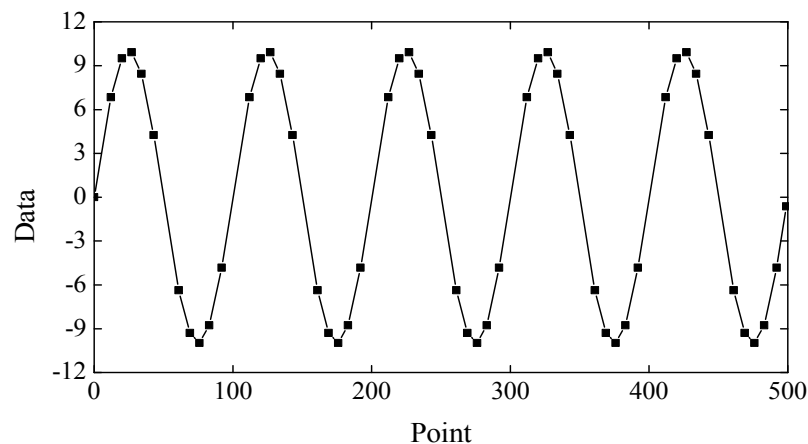


Fig. 6. Compression result of a standard sinusoidal signal using the spinning door transformation with compression threshold value of 1 %.

Fig. 7 shows the compression results of a measured dynamic pressure signal using the linear method and the spinning door transformation with a compression threshold value of 5 %. The measured dynamic pressure signal contains both low and high frequency components, and its sampling frequency is 1000 Hz with 2000 points. The results show that the linear method and the spinning door transformation have a compression ratio of 1.96:1 and 1.59:1, and after decompression their average absolute error are 0.12 and 0.21, respectively.

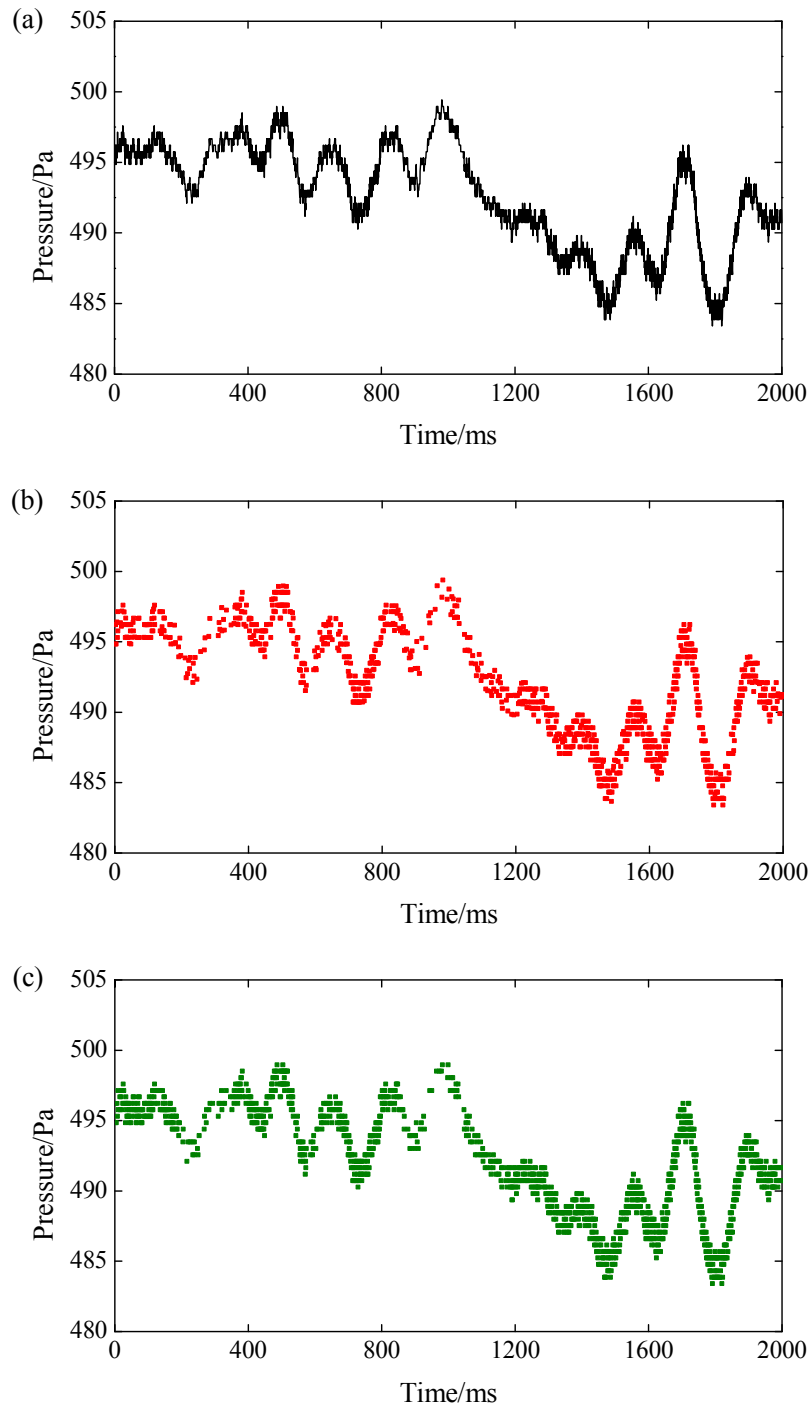


Fig. 7. Compression results of a dynamic pressure signal using linear method and spinning door transformation:
 (a) Original dynamic pressure signal; (b) Compression result of the linear compression;
 (c) Compression result of the spinning door transformation.

According to the results of the above two typical signals, it is seen that the linear compression method has better compression performance at both original data, it not only has higher compression ratio, but also it can keep the local characteristics of the original signal better.

4. Conclusions

This paper presents a new linear method of lossy data compression for effective and efficient utilization of sequential sensor signals. In the course of compression, the filtering and encapsulation are carried out first according to the signal type and the threshold value; second, the linear compression is conducted by comparing the maximum and minimum slopes of the sensor signal; third, the compressed signal is archived into the historical data storage zone for later use. Conversely, the signal is reconstructed by linear interpolation during the decompression process. According to the compression results of a standard sinusoidal signal and a measured dynamic pressure signal, it is found that compared with the spinning door transformation, this method has less compression error and higher compression ratio at the same compression threshold values, and moreover it can keep the local characteristics of the original signal better.

Acknowledgements

We are grateful for the financial support from the National Natural Science Foundation of China (Grant No. 51006125), and the Fundamental Research Funds for the Central Universities of China (Grant No. 2010QZZD0107).

References

- [1]. S. Y. Yurish, Multichannel data acquisition system for smart sensor and transducers, *Sensors & Transducers*, Vol. 8, Issue 2, 2010, pp. 1-12.
- [2]. P. Singh, R. D. S. Yadava, A fusion approach to feature extraction by wavelet decomposition and principal component analysis in transient signal processing of SAW odor sensor array, *Sensors & Transducers*, Vol. 126, Issue 3, 2011, pp. 64-73.
- [3]. P. A. Langen, The use of historical data storage and retrieval systems at nuclear power plants, *IEEE Transactions on Nuclear Science*, Vol. 31, Issue 1, 1984, pp. 844-848.
- [4]. J. C. Hale, H. L. Sellas, Historical data recording for process computers, *Chemical Engineering Progress*, Vol. 77, Issue 11, 1981, pp. 38-43.
- [5]. R. S. H. Mah, A. C. Tamhanea, S. H. Tunga, et al., Process trending with piecewise linear smoothing, *Computers and Chemical Engineering*, Vol. 19, Issue 2, 1995, pp. 129-137.
- [6]. R. M. Gray, Vector quantization, *IEEE ASSP Magazine*, Vol. 1, Issue 2, 1984, pp. 4-29.
- [7]. J. F. MacGregor, T. Kourti, Statistical process control of multivariate process, *Control Engineering Practice*, Vol. 3, Issue 3, 1995, pp. 403-414.
- [8]. B. R. Bakshi, G. Stephanopoulos, Representation of process trends III: multi-scale extraction of trends from process data, *Computers and Chemical Engineering*, Vol. 18, Issue 4, 1994, pp. 267-302.
- [9]. B. R. Bakshi, G. Stephanopoulos, Representation of process trends IV: induction of real-time patterns from operating data for diagnosis and supervisory control, *Computers and Chemical Engineering*, Vol. 18, Issue 4, 1994, pp. 303-332.
- [10]. B. R. Bakshi, G. Stephanopoulos, Compression of chemical process data by functional approximation and feature extraction, *AIChE Journal*, Vol. 42, Issue 2, 1996, pp. 477-492.
- [11]. A. Singhal, D. Seborg, Effect of data compression on pattern matching in historical data, *Industrial & Engineering Chemistry Research*, Vol. 44, Issue 9, 2005, pp. 3203-3212.
- [12]. S. A. Imtiaz, M. Choudhury, S. L. Shah, Building multivariate models from compressed data, *Industrial & Engineering Chemistry Research*, Vol. 46, Issue 2, 2007, pp. 481-491.

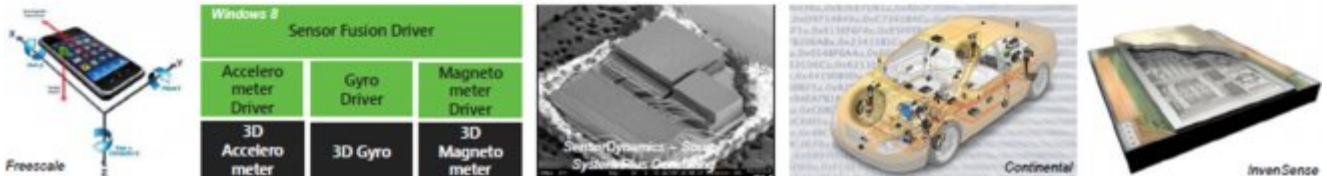
Inertial Combo Sensors for Consumer & Automotive

Technology, Applications, Industry & Market Report to 2016

Promoted by
IFSA

This report is focused on the analysis of the opportunities and the challenges for inertial combo sensors in those high-volume market areas.

http://www.sensorsportal.com/HTML/Inertial_Combo_Sensors_Market.htm



Uncooled Infrared Imaging Market: Commercial & Military applications

Market & Technology Report to 2016

Promoted by
IFSA

This new 2011 IR report, is an updated and in depth analysis of commercial markets covered in the 2010 report in addition we have included a new analysis of the military markets.

http://www.sensorsportal.com/HTML/Detectors_for_Thermography.htm



MEMS & Sensors for Smartphones

TECHNOLOGY & MARKET REPORT - JULY 2010

IFSA offers a SPECIAL PRICE

Report provides:

- market data on MEMS & sensors for mobile phones: key market metrics & dynamics
- application focus on key sensors that are changing the mobile phone industry: new features, technical roadmap, insight about future technology trends & challenges
- a deep understanding of MEMS & sensors value chain, infrastructure & players for the handset business

http://www.sensorsportal.com/HTML/MEMS_and_Sensors_for_smartphones.htm



Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In addition, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

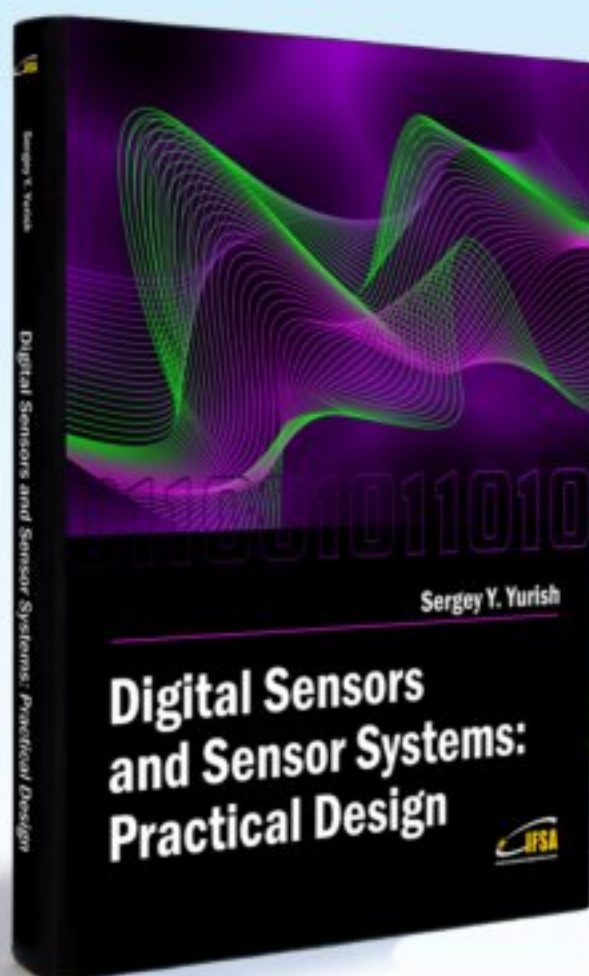
Submission of papers

Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 8-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: <http://www.sensorsportal.com/HTML/DIGEST/Submission.htm> Authors must follow the instructions strictly when submitting their manuscripts.

Advertising Information

Advertising orders and enquires may be sent to sales@sensorsportal.com Please download also our media kit: http://www.sensorsportal.com/DOWNLOADS/Media_Kit_2012.pdf

Digital Sensors and Sensor Systems: Practical Design will greatly benefit undergraduate and at PhD students, engineers, scientists and researchers in both industry and academia. It is especially suited as a reference guide for practitioners, working for Original Equipment Manufacturers (OEM) electronics market (electronics/hardware), sensor industry, and using commercial-off-the-shelf components, as well as anyone facing new challenges in technologies, and those involved in the design and creation of new digital sensors and sensor systems, including smart and/or intelligent sensors for physical or chemical, electrical or non-electrical quantities.



"It is an outstanding and most completed practical guide about how to deal with frequency, period, duty-cycle, time interval, pulse width modulated, phase-shift and pulse number output sensors and transducers and quickly create various low-cost digital sensors and sensor systems ..." (from a review)

Order online:

http://www.sensorsportal.com/HTML/BOOKSTORE/Digital_Sensors.htm



www.sensorsportal.com