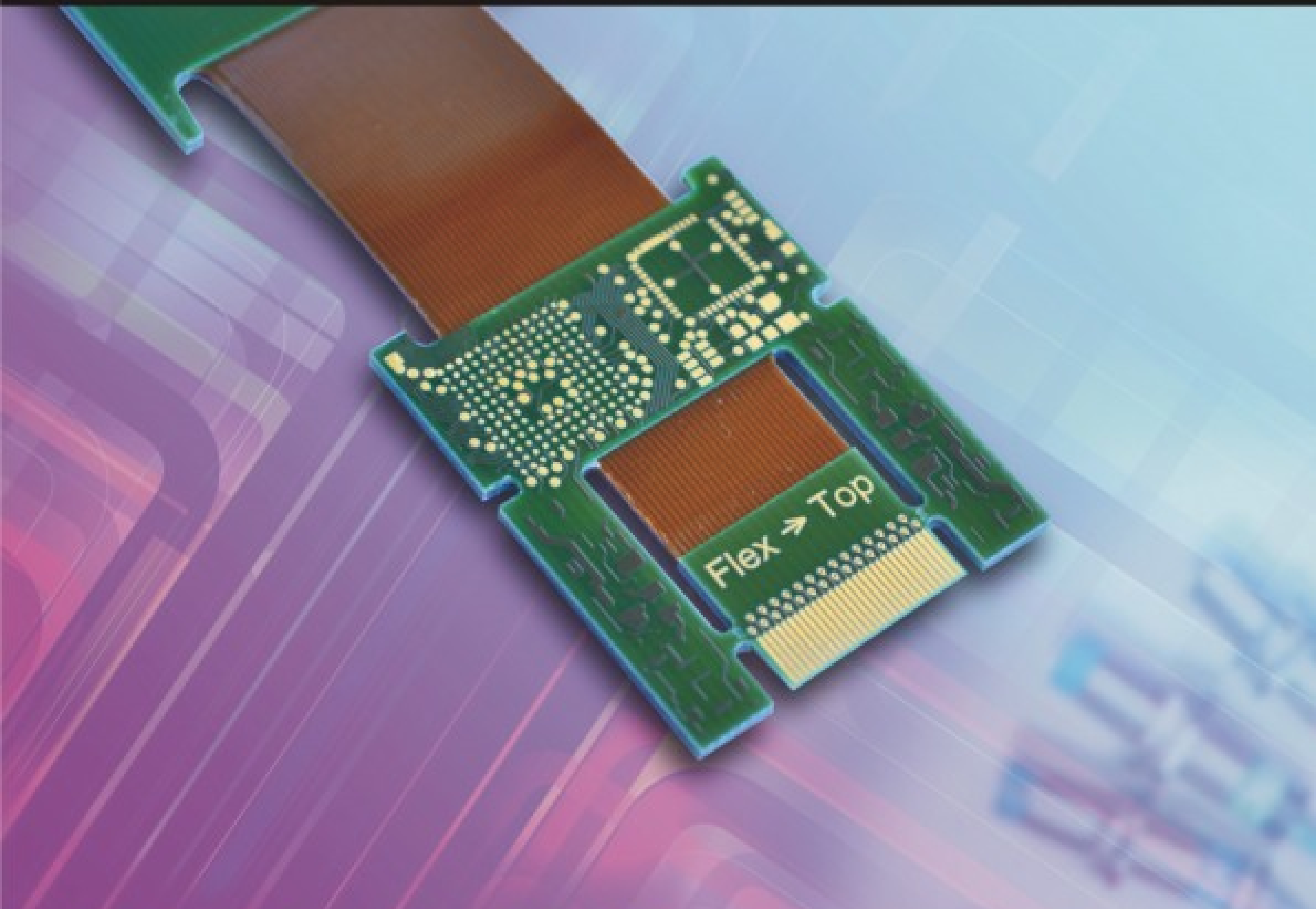
ISSN 1726-5479

SENSORS & TRANSDUCERS

vol. 152
5/13



Sensor Buses and Interfaces

International Frequency Sensor Association Publishing

Sensors & Transducers

International Official Journal of the International Frequency Sensor Association (IFSA) Devoted to Research and Development of Sensors and Transducers

Volume 152, Issue 5, May 2013

IFSA Publishing: Barcelona • Toronto

Printed in the USA.

Sensors & Transducers

Volume 152, Issue 5, May 2013 | **www.sensorsportal.com** | **ISSN 2306-8515 e-ISSN 1726-5479**

Sensors & Transducers Journal (ISSN 2306-8515) is a peer review international journal published monthly online by International Frequency Sensor Association (IFSA). Available in both: print and electronic (printable pdf) formats.

Sensors & Transducers Journal

Contents

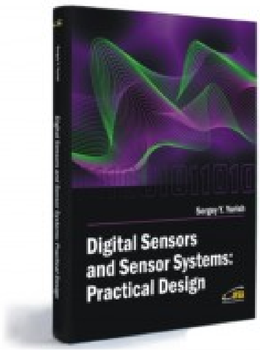
Volume 152
Issue 5
May 2013

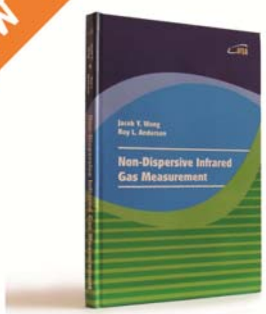
www.sensorsportal.com

ISSN: 2306-8515
e-ISSN 1726-5479

Research Articles

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/Submition.htm


Sergey Y. Yurish
Digital Sensors and Sensor Systems: Practical Design


Non-Dispersive Infrared Gas Measurement

Sensors & Transducers, Vol. 152, Issue 5, May 2013, pp. 84-88

Sensors & Transducers

http://www.sensorsportal.com

A Novel Intelligent Transportation Control Supported by Wireless Sensor Network

[1] Zhe Qian, [2*] Jianqi Liu

[1] School of Civil Engineering and Transportation, South China University of Technology, Guangzhou, 510000, China

[2] College of Information Engineering, Guangdong Jidian Polytechnic, Guangzhou, 510515, China

E-mail: qianz1978@gmail.com, liujianqi@ieee.org

Received: 14 April 2013 /Accepted: 15 May 2013 /Published: 27 May 2013

Abstract: With the development of wireless sensor unit, and improvement of real-time and quality of wireless communication, the intelligent transportation control system employ these technologies to realize sensing, positioning, computing, and communication for voiding collisions. This paper discusses the framework of transportation control system, and emphases TDOA positioning algorithm and the new weighted least square optimization method. The simulation result shows that, our method achieves high-accuracy of positioning, which can satisfy the need of transportation control. Finally, we outline the urgent work need to address in the future. *Copyright © 2013 IFSA.*

Keywords: Intelligent transportation control, Wireless positioning, TDOA, Vehicular wireless sensor network, Weighted least square.

1. Introduction

With the ever increasing production of vehicles and their inevitable role in everyday life, transportation systems are drawing the attention of industry and academia more than any other time. Despite the undeniable beneficial aspects of transportation systems, there are numerous factors by which they impair our everyday life. Without any doubt, many of us have experienced being trapped in heavy traffic, wasting our time and energy resources [1]. While six million car accidents [2] and a combined cost of accidents and congestion totaling $232 billion [3] are reported annually in the United States, there is a critical role for connecting vehicles wirelessly before the onset of collisions and congestion. More than 57 % of system failures can be directly or indirectly attributed to human errors such as inattention, lack of cooperation, and poor decisions [4]. Integrating sensing, positioning, computing, and communication components into these physical entities will result in a novel intelligent transportation control system that minimizes human errors and thus revolutionizes system operation.

If a car passes through the crossroad with speed of 40 km per hour, the novel intelligent transportation control should know the location of at first [5, 6]. Then, the researchers will integrate vehicle dynamics and communication with a field theory model to predict vehicle motion for identifying safety hazards and proactive collision warning, and mine traffic data for dynamic vehicle routing [7, 8]. So, the accurate positioning is the basic of transportation control.

The remainder of this paper is organized as follows: We discuss the related work of transportation control system in Section 2. In Section 3, we emphasis the high accuracy positioning technology for vehicle. Section 4 outlines the simulation result, and Section 5 concludes this paper.

2. Related Work

In the near future, The novel transportation control system envisions that each future vehicle will be equipped with an On-Board Equipment (OBE) which includes a Dedicated Short Range Communications (DSRC) [9] transceiver, a high accuracy positioning system transceiver, a processing unit, and possibly appropriate sensing accessories. Also equipped with similar devices, Road Side Equipment (RSE) will be deployed at selected roadside locations. Therefore, vehicles will be able to communicate with each other and with the roadside by means of wireless sensor network (WSN). Thus, as sketched in the Fig. 1, these components will form vehicular wireless sensor networks (VWSN), within which connected vehicles will be able to “talk” to each other. Envisioned in each OBE is a Co-Driver that will proactively monitor safety hazards in its vicinity and warn the human driver of any imminent collision. Meanwhile, an RSE can retrieve data logged in an OBE when its host vehicle passes by. Through wireless communications, such data are shared with other RSEs. Hence, the RSE is able to maintain a dynamic traffic map of the entire network, which can be queried by the Co-Driver. As such, the Co-Driver is able to advise its human driver optimal routes to avoid collision.

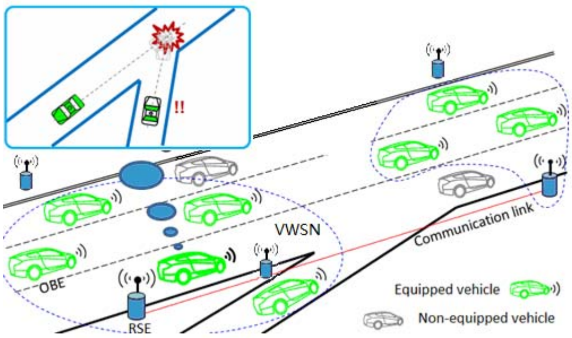


Fig. 1. Overview of intelligent transportation control system.

The one of key issues of intelligent transportation control is positioning. The accurate location of vehicle is basic of safety hazard predication. As the low positioning accuracy of Global Positioning System (GPS), we should develop a new wireless positioning technology. The high accuracy positioning technology will discuss in next section in detail.

3. Wireless Positioning

Although vehicle passive (e.g. seatbelts and air bags) and active (e.g. adaptive cruise control) systems have been developed to improve safety, a proactive system can complement the above systems to transform vehicle safety by looking forward in time to identify potential safety hazard. Positioning plays an important role in the transportation system. If a control unit of vehicle have ability to track the location of himself and other vehicle around him, such capabilities would greatly improve safety. GPS is the most widely used satellite-based positioning system that offers maximum coverage, but the positioning accuracy of GPS only achieve about 3 m [10], which can not satisfy the need of transportation control. In recent years, wireless sensor networks' low-power organization, heterogeneous interconnect and other key technologies to achieve greater research progress. Ultra Wideband (UWB) is favorable alternative. UWB has good real-time performance, which supports continued up to 160 HZ refresh rate, which means that each sensor or positioning unit to locate the target speed of 6.25 ms. Meanwhile, within a distance of 10 meters , UWB can play up to 500 Mbps transmission performance [11-13]. In VWSN of transportation control system, we use UWB radio as the communication medium to realize the function of positioning.

The positioning algorithms can be categorized according to different criteria. One way of classifying positioning algorithm is on the system computing way. The algorithms can be grouped as centralized computation positioning and distributed computation positioning [5, 14-17]. Centralized computation positioning algorithm is controlled through a central terminal server, which centrally provides the processing, calculating, wireless communicating and storage. Every node has its own process unit for processing, communicating and storage in distributed computation positioning algorithm. There is an advantage of centralized positioning algorithm. It can obtain relatively more accurate location estimation than distribute positioning. Since centralized server owns unlimited calculation ability and storage capacity [16, 18-20]. The centralized positioning algorithm is adopted in transportation control system. Now, we emphasis on discussion of time difference of arrival (TDOA) positioning algorithm in this paper.

The TDOA algorithm can be seen as the intersection of hyperbolas in 2D plane. Positioning systems that use the TDOA algorithm measure the difference in transmission times between signals received from each of the target (mobile vehicle) to RSEs, whose location is known. TDOA requires the RSEs record any received signal. TDOA requires that each signal be transmitted synchronously, either at the same time or with some known delay occurring in signal transmissions.

A 2-D target location can be estimated from the two intersections of two or more TDOA measurements. Three RSEs (N_0, N_1, and N_2) are required, whose location is pre-established.

Each of the RSEs receives a signal synchronously from the target and record when the signal is received. This information is forwarded to a positioning server which calculates the received signal's time difference between each of the anchor nodes. This difference is transformed through an algorithm to provide an estimated location of the target. Mathematically, the target node is located at the intersection of hyperbolas in a 2D plane. The location of a mobile transmitter in a 2D plane can be illustrated in Fig. 2. The equation is given by

$$\begin{aligned} ct_{01} &= \sqrt{(x-x_0)^2+(y-y_0)^2} \\ &\quad -\sqrt{(x-x_1)^2+(y-y_1)^2} = D_0 - D_1 \\ ct_{02} &= \sqrt{(x-x_0)^2+(y-y_0)^2} \\ &\quad -\sqrt{(x-x_2)^2+(y-y_2)^2} = D_0 - D_2 \end{aligned} \tag{1}$$

where (x_0, y_0), (x_1, y_1), and (x_2, y_2) represent the coordinate of anchor nodes (N_0, N_1 and N_2) respectively, and (x, y) represents the mobile transmitter. The t_{01} represents the difference of time arrive of N_0 and N_1. According to simultaneous formulas, (x, y) can be deduced. But only depend on three anchor nodes, the precision of location can not be guaranteed. In order to increase the positioning accuracy, we introduce least square (LS) method into TDOA algorithm [21].

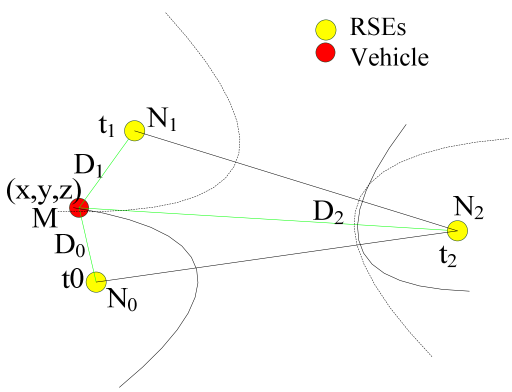


Fig. 2. Positioning based on TDOA algorithm.

Assume the amount of all anchor nodes is n, for each anchor node i, $i \in [1, n]$, the distance d_{0i} relative to anchor node N_0 can be derived from following equation

$$\begin{aligned} d_{oi} &= ct_{0i} = \sqrt{(x-x_0)^2+(y-y_0)^2} \\ &-\sqrt{(x-x_i)^2+(y-y_i)^2} = D_0 - D_i, \end{aligned} \tag{2}$$

where

$$\begin{aligned} D_0^2 - D_i^2 &= \|M - N_0\|^2 - \|M - N_i\|^2 \\ &= ((x-x_0)^2 + (y-y_0)^2) \\ &\quad - ((x-x_i)^2 + (y-y_i)^2) \\ &= x_0^2 - x_i^2 + 2x(x_i - x_0) + y_0^2 \\ &\quad - y_i^2 + 2y(y_i - y_0) \\ &= D_0^2 - (D_0 - d_{0i})^2 \\ &= 2D_0 d_{0i} - d_{0i}^2 \end{aligned} \tag{3}$$

Group all the known terms together and denote

$$b_i = \frac{1}{2}\left[x_0^2 - x_i^2 + y_0^2 - y_i^2 + d_{0i}^2\right] \tag{4}$$

which is a linear model for unknown parameters (x, y) and D_0. Stacking the n nodes measurement, we have the linear system in matrix form

$$AX = b \tag{5}$$

where

$$A = \begin{bmatrix} x_0 - x_1 & y_0 - y_1 & d_{01} \\ x_0 - x_2 & y_0 - y_2 & d_{02} \\ \vdots & \vdots & \vdots \\ x_0 - x_n & y_0 - y_n & d_{0n} \end{bmatrix}$$

$$X = \begin{bmatrix} x \\ y \\ D_0 \end{bmatrix}, \quad b = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{bmatrix}$$

When the location of nodes can be precisely known and the TDOA measurements are noise-free, linear system is compatible. The solution is unique while the data matrix A is of full rank. Let e represents the error of observation value and ideal value.

$$\begin{aligned} &\sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n} (b_i - b_{lsi})^2 \\ &\Rightarrow E^{\mathrm{T}}E = (b - AX)^{\mathrm{T}}(b - AX) \end{aligned} \tag{6}$$

where

$$E = \begin{bmatrix} e_1 & e_2 & \cdots & e_n \end{bmatrix}^{\mathrm{T}}$$

According to least square principle, we conduct the derivative of equation (6). We have

$$\partial(b - AX)^T(b - AX)/\partial X = 0 \tag{7}$$

Once a minimizing b_{ls} is found, then any X satisfying $AX = b_{ls}$ can be called an LS solution and $b - b_{ls}$ the corresponding LS correction. The unique LS solution can be obtained while the data matrix A is of full rank:

$$X_{ls} = \left(A^T A\right)^{-1} A^T b \quad (8)$$

Finally, the location (x, y) is deduced.

For better performance, we can add a weighting matrix W to (7). This leads to the following constrained optimization problem:

$$\partial((b - AX)^T W(b - AX))/\partial X = 0 \quad (9)$$

We will obtain matrix representation as formula (10).

$$X_{WLS} = (A^T (W + W^T)A)^{-1} A^T (W + W^T)b \quad (10)$$

4. Simulation Result

Computer simulations had been conducted to evaluate the performance of the proposed TDOA-based positioning algorithms for transportation control. We considered a five-anchor nodes geometry with coordinates (0, 0) cm, (0, 2000) cm, (2000, 0) cm, (2000, 2000) cm, and (1000, 1000) cm, and a mobile node (500, 500) cm. All results were averages of 1000 independent runs.

Fig. 3 top left corner plots the 25 dBW white Gaussian noise (WGN) of the LS, WLS method; top right corner shows the LS estimator; lower left corner illustrates the WLS estimator; lower right corner plots the error of two methods and average error. The simulation result shows the average positioning accuracy of WLS method is 12.9075 cm.

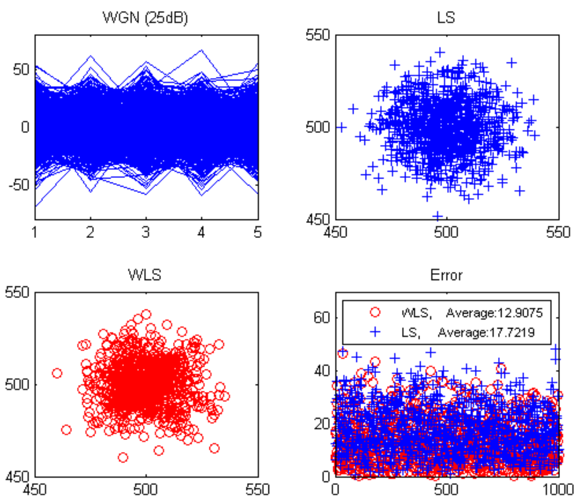


Fig. 3. The estimated result of the LS and WLS estimator at (x, y)= (500; 500) cm under 25 dBW noise.

Meanwhile, we test the LS and WLS method under 15 dBW noise, the average accuracy of WLS positioning method is 3.9689 cm. The simulation result is shown in Fig. 4.

From the simulation result, the average error of WLS based UWB is less than 15 cm in the 20 m^2 coverage of crossroads under 25 dBW and 4cm under 15 dBW, which can satisfy the requirement of transportation control.

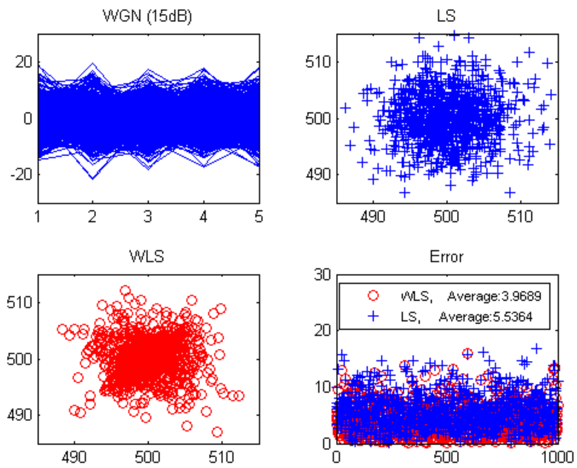


Fig. 4. The estimated result of the LS and WLS estimator at (x, y)= (500; 500) cm under 15 dBW noise.

5. Conclusion

The successful accomplishment of positioning provide an innovative method and paradigm for accurate travel time prediction that is able to best utilize the information generated by both connected vehicles and traditional traffic detectors.

However, there are some issue need to address in near future. Firstly, a dynamic vehicle routing algorithm will be developed that will fundamentally change how the existing in-vehicle navigation systems work. This algorithm will be able to effectively avoid the potentially dynamic all-or-nothing assignment results, and move the network traffic flow towards a state of dynamic system optimal. Secondly, mine traffic data for dynamic vehicle routing. Based on vehicle wireless communication network, we will develop new algorithms to estimate and predict travel time in real time, and combine the result with accident prediction to support dynamic route choice for drivers to avoid congestion. Finally, energy-saving is also a problem need to solve.

Acknowledgements

The authors would like to thank the Natural Science Foundation of Guangdong Province, China (No.9151009001000021, S2011010001155), the Ministry of Education of Guangdong Province Special Fund Funded Projects through the

Cooperative of China (No. 2009B090300 341), the National Natural Science Foundation of China (No. 61262013), the High-level Talent Project for Universities, Guangdong Province, China (No. 431, Yue Cai Jiao 2011), and the Chinese Society of Vocational and Technical Education 2012-2013 scientific research and planning projects (No. 204921) for their support in this research.

References

[1]. M. Nekoui, H. Pishro-Nik, and D. Ni, The effect of intellidrive on the efficiency of highway transportation systems, *International Journal of Vehicular Technology*, Vol. 2011, 2011.

[2]. National Transportation Statistics 2011. (http://www.bts.gov/publications/national_transportation_statistics/), 2011.

[3]. C. Clifford. U. S. car accident cost, *CNNMoney.com*, 2008.

[4]. Distracted driving, National Highway Traffic Safety Administration (NHTSA), (http://www.distraction.gov/index. html), 2011.

[5]. J. Wan, H. Suo, H. Yan, et al., A General Test Platform for Cyber-Physical Systems: Unmanned Vehicle with Wireless Sensor Network Navigation, *Procedia Engineering*, Vol. 24, 2011, pp. 123-127.

[6]. M. Chen, J. Wan, and F. Li, Machine-to-Machine Communications: architectures, standards, and applications, *KSII Transactions on Internet and Information Systems*, Vol. 6, 2012, pp. 480-497.

[7]. M. Chen, C. F. Lai, and H. Wang, Mobile multimedia sensor networks: architecture and routing, *EURASIP Journal on Wireless Communications and Networking*, Vol. 2011, 2011, pp. 1-9.

[8]. M. Chen, V. C. M. Leung, and S. Mao, Cooperative Geographical Routing in Wireless Sensor Networks, Handbook on Sensor Networks, Yang Xiao, Hui Chen, and Frank H. Li, *World Scientific Publishing Co*, 2009.

[9]. ITS, Intellidrive, (http://www.its.dot.gov/intellidrive/).

[10]. B. Hofmann-Wellenhof, H. Lichtenegger, and J. Collins, Global Positioning System: Theory and Practice, *Springer*, Viena, Austria, 2001.

[11]. A. De Angelis, J. Nilsson, I. Skog, et al., Indoor Positioning by Ultrawide Band Radio Aided Inertial Navigation, *Metrology and Measurement Systems*, Vol. XII, 2010, pp. 447-460.

[12]. J. R. Fernandes and D. Wentzloff, Recent advances in IR-UWB transceivers: An overview, in *Proceedings of the 2010 IEEE International Symposium on Circuits and Systems (ISCAS)*,, 2010, pp. 3284-3287.

[13]. R. J. Fontana, Recent system applications of short-pulse ultra-wideband (UWB) technology, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 52, 2004, pp. 2087-2104.

[14]. R. Want, A. Hopper, V. Falcão, et al., The active badge location system, *ACM Transactions on Information Systems (TOIS)*, Vol. 10, 1992, pp. 91-102.

[15]. J. Liu, Q. Wang, J. Wan, et al., Towards Real-Time Indoor Localization in Wireless Sensor Networks, in *Proceedings of the IEEE 12th International Conference on Computer and Information Technology (CIT)*, 2012, pp. 877-884.

[16]. H. Suo, J. Wan, L. Huang, et al., Issues and Challenges of Wireless Sensor Networks Localization in Emerging Applications, in *Proceedings of the Int. Conf. on Computer Science and Electronics Engineering*, Hongzhou, 2012, pp. 447-451.

[17]. J. Wan, H. Yan, H. Suo, et al., Advances in Cyber-Physical Systems Research, *KSII Transactions on Internet and Information Systems*, Vol. 5, 2011, pp. 1891-1908.

[18]. A. Savvides, C.-C. Han, and M. B. Strivastava, Dynamic fine-grained localization in ad-hoc networks of sensors, in *Proceedings of the 7th Annual International Conference on Mobile Computing and Networking*, 2001, pp. 166-179.

[19]. F.-B. Wang, L. Shi, and F.-Y. Ren, Self-localization systems and algorithms for wireless sensor networks, *Ruan Jian Xue Bao (J. Softw.)*, Vol. 16, 2005, pp. 857-868.

[20]. A. Savvides, H. Park, and M. B. Srivastava, The bits and flops of the n-hop multilateration primitive for node localization problems, in *Proceedings of the 1st ACM International Workshop on Wireless Sensor Networks and Applications*, 2002, pp. 112-121.

[21]. Y. Weng, W. Xiao, and L. Xie, Total Least Squares Method for Robust Source Localization in Sensor Networks Using TDOA Measurements, *International Journal of Distributed Sensor Networks*, Vol. 2011, 2011.


IARIA
The Fourth International Conference on Sensor Device Technologies and Applications
SENSORDEVICES 2013
25 - 31 August 2013 - Barcelona, Spain
Tracks: Sensor devices - Ultrasonic and Piezosensors - Photonics - Infrared - Gas Sensors - Geosensors - Sensor device technologies - Sensors signal conditioning and interfacing circuits - Medical devices and sensors applications - Sensors domain-oriented devices, technologies, and applications - Sensor-based localization and tracking technologies - Sensors and Transducers for Non-Destructive Testing
Deadline for papers: 30 March 2013
http://www.iaria.org/conferences2013/SENSORDEVICES13.html


IARIA
The Seventh International Conference on Sensor Technologies and Applications
Deadline for papers: 30 March 2013
SENSORCOMM 2013
25 - 31 August 2013 - Barcelona, Spain
Tracks: Architectures, protocols and algorithms of sensor networks - Energy, management and control of sensor networks - Resource allocation, services, QoS and fault tolerance in sensor networks - Performance, simulation and modelling of sensor networks - Security and monitoring of sensor networks - Sensor circuits and sensor devices - Radio issues in wireless sensor networks - Software, applications and programming of sensor networks - Data allocation and information in sensor networks - Deployments and implementations of sensor networks - Under water sensors and systems - Energy optimization in wireless sensor networks
http://www.iaria.org/conferences2013/SENSORCOMM13.html


IARIA
The Sixth International Conference on Advances in Circuits, Electronics and Micro-electronics
CENICS 2013
25 - 31 August 2013 - Barcelona, Spain
Deadline for papers: 30 March 2013
Tracks: Semiconductors and applications - Design, models and languages - Signal processing circuits - Arithmetic computational circuits - Microelectronics - Electronics technologies - Special circuits - Consumer electronics - Application-oriented electronics
http://www.iaria.org/conferences2013/CENICS13.html

Aims and Scope

Sensors & Transducers is a peer reviewed international, interdisciplinary journal that provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes original research articles, timely state-of-the-art reviews and application specific articles with the following devices areas:

- 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 and interfacing;
- Frequency (period, duty-cycle)-to-code converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

Further information on this journal is available from the Publisher's web site:
http://www.sensorsportal.com/HTML/DIGEST/Submission.htm

Subscriptions

An annual subscription includes 12 regular issues and some special issues. Annual subscription rates for 2013 are the following:

Electronic version (in printable pdf format): 400.00 EUR
Printed with b/w illustrations: 640.00 EUR
Printed full color version: 760.00 EUR

40 % discount is available for IFSA Members.

Prices include shipping costs by mail. Further information about subscription is available through IFSA Publishing's web site: http://www.sensorsportal.com/HTML/DIGEST/Journal_Subscription.htm

Advertising Information

Books for Review

Publications should be sent to the IFSA Publishing Office: Ronda de Ramon Otero Pedrayo, 42C, 1-5, 08860, Castelldefels, Barcelona, Spain.

Abstracting Services

This journal is cited, indexed and abstracted by Chemical Abstracts, EBSCO Publishing, IndexCopernicus Journals Master List, ProQuest Science Journals, CAS Source Index (CASSI), Ulrich's Periodicals Directory, Scirus, Google Scholar, etc. Since 2011 *Sensors & Transducers* journal is covered and indexed by EI Compendex index (including a Scopus, Embase, Engineering Village and Reaxys) in *Elsevier* products.

Instructions for Authors

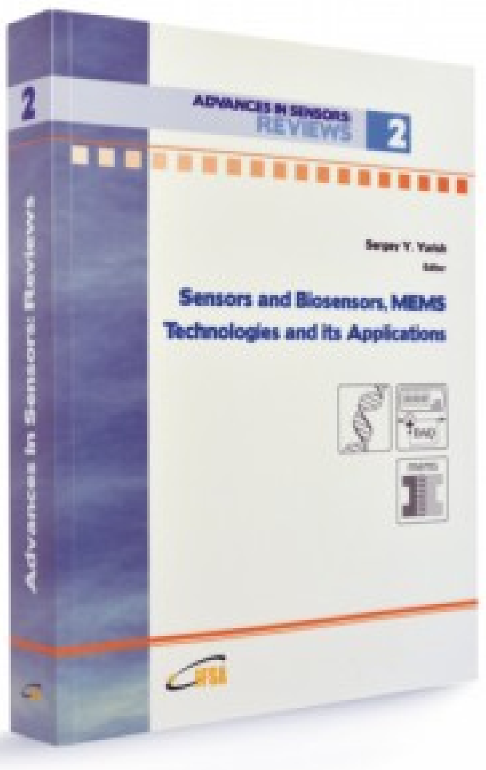
Please visit the journal web page http://www.sensorsportal.com/HTML/DIGEST/Submission.htm Authors must follow the instructions very carefully when submitting their manuscripts. Manuscript must be send electronically in both: MS Word 2003 for Windows (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com

International Frequency Sensor Association Publishing

ADVANCES IN SENSORS: REVIEWS 2

Sergey Y. Yurish
Editor

Sensors and Biosensors, MEMS Technologies and its Applications



The second volume titled '*Sensors and Biosensors, MEMS Technologies and its Applications*' from the '*Advances in Sensors: Review*' Book Series contains eighteen chapters with sensor related state-of-the-art reviews and descriptions of the latest achievements written by experts from academia and industry from 12 countries: China, India, Iran, Malaysia, Poland, Singapore, Spain, Taiwan, Thailand, UK, Ukraine and USA.

This book ensures that our readers will stay at the cutting edge of the field and get the right and effective start point and road map for the further researches and developments. By this way, they will be able to save more time for productive research activity and eliminate routine work.

Built upon the series *Advances in Sensors: Reviews* - a premier sensor review source, it presents an overview of highlights in the field and becomes. This volume is divided into three main parts: physical sensors, biosensors, nanoparticles, MEMS technologies and applications. With this unique combination of information in each volume, the *Advances in Sensors: Reviews* Book Series will be of value for scientists and engineers in industry and at universities, to sensors developers, distributors, and users.

Like the first volume of this Book Series, the second volume also has been organized by topics of high interest. In order to offer a fast and easy reading of the state of the art of each topic, every chapter in this book is independent and self-contained. The eighteen chapters have the similar structure: first an introduction to specific topic under study; second particular field description including sensing applications.

Order online:
http://sensorsportal.com/HTML/BOOKSTORE/Advance_in_Sensors_Vol_2.htm

www.sensorsportal.com

ISSN 1726- 5479

9 771726 547001