# **Pacific PNT Meeting 2019**

Honolulu, Hawaii, USA 8 – 11 April 2019

Volume 1 of 2

ISBN: 978-1-7138-0582-3

Printed from e-media with permission by:

Curran Associates, Inc. 57 Morehouse Lane Red Hook, NY 12571



Some format issues inherent in the e-media version may also appear in this print version.

Copyright<sup>©</sup> (2019) by Institute of Navigation All rights reserved.

Printed with permission by Curran Associates, Inc. (2020)

For permission requests, please contact Institute of Navigation at the address below.

Institute of Navigation 8551 Rixlew Lane Suite 360 Manassas, VA 20109 USA

Phone: (703) 366-2723 Fax: (703) 366-2724

membership@ion.org

#### Additional copies of this publication are available from:

Curran Associates, Inc. 57 Morehouse Lane Red Hook, NY 12571 USA Phone: 845-758-0400 Fax: 845-758-2633 Email: curran@proceedings.com Web: www.proceedings.com

#### **PLENARY: Policy and Status Update**

Update on the BeiDou Navigation Satellite System (BDS)	1 - 28
Jun Shen	1 - 20
<b><u>COSMIC/FORMOSAT: Ionospheric Weather Observed by GNSS Radio</u> <u>Occultation</u></b>	29 - 35
Tiger J.Y. Liu and CAPE Group	55
Future of Space-based PNT David C. Chapman	36 - 51

#### BDS

Research on Standalone BeiDou Radio Frequency Minimum Performance Test for	50
Mobile Communication Terminals	52 -
Zhang Qinjuan, Dai Xun, Chen Xiaochen Peer Reviewed	57

# Alternative Navigation and Signals of Opportunity

<b>Robust Low-Latency Indoor Localization Using Bluetooth Low Energy</b>	
Haojun Ai, Sheng Zhang, Kaifeng Tang, Ning Li, Weiyi Huang, Yifeng Wang Peer	58 -
Reviewed	72
Presentation File	
Crowd-sensing Simultaneous Localization and Radio Fingerprint Mapping Based	
<u>on Probabilistic Similarity Models</u>	73 -
Ran Liu, Sumudu Hasala Marakkalage, Madhushanka Padmal, Thiruketheeswaran	83
Shaganan, Chau Yuen, Yong Liang Guan, U-Xuan Tan Peer Reviewed	85
Presentation File	
Initialization of a Pedestrian Navigation System: A Transfer Alignment Approach	84 -
Archit Thopay, David Bevly, Scott Martin Peer Reviewed	97
<u>Urban Wi-Fi Fingerprinting for Routing of Multi-modal Transport Users</u>	98 -
Guenther Retscher, Aizhan Bekenova Peer Reviewed	107
Toward GPS-denied Navigation Utilizing Back Projection-based Synthetic	
Aperture Radar Imagery	108
Randall S. Christensen, Jacob Gunther, David Long Peer Reviewed	119
Presentation File	
Development of an Implementation-Agnostic Quality Metric for Evaluating the	120
Accuracy of Position Estimations from Vision-Based Navigation Algorithms	120
Jacob Stewart, Michael Payne, Gregory Reynolds, Kelly Risko, Clinton Blankenship	129

#### **Algorithms and Methods 1**

An Adaptive Method for BeiDou Dual-Frequency Joint Acquisition Based on SNR	
Estimation	130 -
Wuxun Zhang, Xin Chen, Di He, Yueming Yang Peer Reviewed	141
Presentation File	

Autonomous and Resilient Management of All-Source Sensors	142 -
Juan D. Jurado and John F. Raquet Peer Reviewed	159
<b>Geolocation of Pulses Using Bispherical Coordinates and Multiple Omnidirectional</b>	
Receivers	160 -
George N. Gilliam, Tracie A. Severson Peer Reviewed	170
Presentation File	
Barometer Assisted GPS Denied Trilateration Algorithm for Traversing Vertical	
Three-Dimensional Spaces	171 -
Alvin Goh Cheng Ann, Alvee Ahmed, Gim Song Soh, Shaohui Foong Peer Reviewed	184
Presentation File	

#### **COSMIC/FORMOSAT**

Ionospheric Weather Observations with FORMOSAT-3/COSMIC and Prospects with FORMOSAT-7/COSMIC-2 Tiger J.Y. Liu, Loren C. Chang, F.Y. Chang, C.K. Chao	185 - 189
Seasonality of the Local-time Variations in Formosat-3/COSMIC S4 Indices and Ionospheric Electron Density Cornelius Csar Jude H. Salinas, Loren C. Chang Peer Reviewed	190 - 198
Performance Assessment and Improvements for the FORMOSAT-5 Onboard Orbit Propagator Using GPS Ephemeris Edward Chi-Ting Liao, Loren C. Chang, Wen-Lung Chiang, Ming-Yu Yeh Peer Reviewed	199 - 205

# **Interference and Spectrum**

Towards a Comprehensive Approach for Obtaining Resilient PNT Logan Scott	206 - 261
Measurement Characterization for Localizing Multiple RFI Sources Simultaneously from a UAS Adrien Perkins, Sherman Lo, J. Dave Powell Peer Reviewed	262 - 273
Accommodating Direction Ambiguities in Direction of Arrival based GNSS Spoof Detection Hridayangam Jain, Sherman Lo, Yu-Hsuan Chen, Fabian Rothmaier, J. David Powell Peer Reviewed Presentation File	274 - 289
Kalman Filter Derivation and Comparison to MUltiple SIgnal Classification(MUSIC)Russell Powell, Caleb Perry, Adam Simmons, Gregory Reynolds, Clinton BlankenshipPeer Reviewed	290 - 303

# Algorithms and Methods 2

<u>Timescale Development for GNSS Applications</u>	304 -
Michael J. Coleman and Ronald L. Beard Peer Reviewed	
Presentation File	317

<b>Bobcat-1: The Ohio University CubeSat for Inter-Constellation Time Offset</b>	210	
Determination	318 -	
Sabrina Ugazio, Kevin Croissant, Brian Casey Peters, Frank van Graas Peer Reviewed	325	
Distance Determination Between WGS84 Coordinates: An Assessment of	226	
Approximation Methods for Reduced Computational Complexity	326 -	
David Seiferth, Christopher Blum, Matthias Heller, Florian Holzapfel Peer Reviewed	339	
Paper Trends in ION Conferences from 2007 - 2018	240	
Adrien Perkins and Todd Walter Peer Reviewed	340 -	
Presentation File	348	

# QZSS

Josh Wilkerson Peer Reviewed

The Operational Phase Performance of Centimeter-Level Augmentation Service	
(CLAS)	349 -
Rui Hirokawa, Kenji Nakakuki, Seigo Fujita, Yuki Sato, Akinari Uehara Peer Reviewed	360
Presentation File	
<b>Evaluation of QZSS SLAS (Sub-meter Level Augmentation Service) Performance</b>	261
Daiki Matsumoto, Takayuki Kaneso, Takashi Urushido, Satoru Owada Peer Reviewed	361 - 366
Presentation File	300
Capturing Method of Millimeter Displacement in Centimeter Class PPP-RTK	
	367 -
Koki Asari, Masayuki Saito, Izumi Mikami Peer Reviewed	375
Presentation File	
Brief Study to Improve Robustness for RTK-GNSS with QZSS (Quasi-Zenith	
Satellite System)	376 -
Hiromune Namie, Nobuaki Kubo, Osamu Okamoto, Hiroki Irie, Masashi Yoshida, Akio	381
Yasuda Peer Reviewed	
DFMC SBAS Prototype System Performance Using Global Monitoring Stations of	202
QZSS	382 - 387
Mitsunori Kitamura, and Takeyasu Sakai	301
Integration of GNSS-PPP and IMU/SPEED Sensors in Urban Areas	388 -
Nobuaki Kubo, Yize Zhang, Daisuke Hatta Peer Reviewed	401
UAS Technologies	
Navigation of Multiple sUAS Using GNSS, Inertial and Range Radios	402 -
	412
New UAV Velocity Estimation Using Array of Hall Effect Sensors for Indoor	
Navigation	413 -
S. Zahran, A.M. Moussa, N. El-Sheimy, Abu B. Sesay Peer Reviewed	423
	424 -
S. Zahran, A.M. Moussa, N. El-Sheimy, Abu B. Sesay Peer Reviewed	423 424 -

438

# **Natural Hazards Detection and Monitoring Using GNSS**

<b>Comparing Detection Techniques of Coseismic Disturbances by using Differential</b>	
Ionospheric Delay of GNSS Signal	439 -
Bugyeom Kim, Seonho Kang, Deokhwa Han, Changdon Kee, Junesol Song Peer	450
Reviewed	
Indoor and Urban Navigation	
Deep Neural Network Based Multipath Mitigation Method for Carrier Based	451
Differential GNSS Systems	451 - 466
Dongchan Min, Minchan Kim, Jinsil Lee, Jiyun Lee Peer Reviewed	400
Railway Navigation	
GPS/BDS-based Virtual Balise - Enabling Satellite-based Train Control with a	4.67
Train-centric Approach	467 -
Jiang Liu, Bai-gen Cai, De-biao Lu, Jian Wang Peer Reviewed	477
Intelligent Antennas for Mitigating GNSS Jamming & Spoofing Hazards on the	
ERTMS Train Control	478 -
Cosimo Stallo, Pietro Salvatori, Andrea Coluccia, Massimo Capozzi, Giovanni Gamba,	492
Ernestina Cianca, Tommaso Rossi, Simone Di Domenico, Alessandro Neri, Francesco	774
Rispoli, Massimiliano Ciaffi Peer Reviewed	
Indoor Vehicle Localization Based on Wi-Fi Navigation Beacons for Multi-Modal	493 -
Transportation Applications	506
Alessandro Neri, Pietro Salvaroti, Massimo Massaro, Francesco Rispoli Peer Reviewed	000
<b>Emerging PNT Consumer Applications</b>	
The Necessary Consideration for More Effective Location Information on E911	
Masaaki Hayashi Peer Reviewed	507 -
Presentation File	518
A Script Hook-based Ultra-Low Cost Driving Simulator for Development of Self-	
Driving Algorithms	519 -
Ji-Ung Im, Sang-Hun Ahn, Jong-Hoon Won Peer Reviewed	528
GNSS Signal in Railway Train Operation Scenario Quality Grid Generation	500
Method	529 -
Debiao Lu, Jun Tan, Baigen Cai, Jiang Liu, Jian Wang Peer Reviewed	539
Lifelog using Mobility Context Information in Urban City Area	540 -
Yanlei Gu, Dailin Li, Yoshihiko Kamiya, Shunsuke Kamijo Best Paper Peer Reviewed	553
Chip-grade Multi-Band Multi-GNSS RTK and Attitude Determination with Low	554 -
Cost Dual Antennas for Mass Market Applications	569

Ryan K.Y. Yang, Shi Xian Yang, Gary Hau Peer Reviewed	
Presentation File	
<b>Generation of Crustal Movement Correction Parameter Considering Valid Period</b>	
and Accuracy Guarantee	570 -
Yuki Ichikawa and Mikihiro Hosoi Peer Reviewed	581
Presentation File	

#### **Inertial Navigation Technology and Applications**

Step-Based Attitude Update (SBUPT) Technique for Pedestrian Dead Reckoning	
(PDR) using Handheld Devices	582 -
Maan E. Khedr, Ahmed Radi, and Naser El-Sheimy Peer Reviewed	593
Presentation File	
Transfer Alignment Using Synergistic IMUs	594 -
Shahram Moafipoor, Brad Despres, Jeff A. Fayman, Lydia Bock Peer Reviewed	605
An Efficient Method for Gyroscope-aided Full Magnetometer Calibration	606 -
Maoran Zhu, Yuanxin Wu, Wenxian Yu Peer Reviewed	614
Indoor Altitude Determination Using MEMS-based Sensors in Smartphones	615 -
Guenther Retscher Peer Reviewed	627
Factor Graph-Based Cooperative Positioning Algorithm for Pedestrian Navigation	628 -
Systems in Indoor Environments	628 - 634
Chunyang Yu, Haiyu Lan, Yiran Luo, Shiwei Fan, Naser El-Sheimy Peer Reviewed	034

#### **GNSS-R and GNSS-RO for Environmental Monitoring**

On the Feasibility of Smartphone-based Interferometric GNSS Reflectometry Mehmet Kurum, Ali Cafer Gurbuz, Claudia, Nelson, Lauren Orsini, Mia Scheider Presentation File	635 - 640
<b>Function and Performance Assessment of a GNSS-R Receiver in Airborne Tests</b> Jyh-Ching Juang, Sheng-Hsiung Ma, Yung-Fu Tsai, Chen-Tsung Lin	641 - 645
A Novel Application of Deformation Monitoring using GNSS-R Technology Yang Yang, Yu Zheng, Wenkun Yu, Duojie Weng, Wenbin Li, Wu Chen	646 - 654
Mountaintop GNSS-R and GNSS-RO Experiment: New Results and Insights Jade Morton, Harrison Bourne, Brian Breitsch, Ian Collett, Steve Taylor, Neeraj Pujara Peer Reviewed	655 - 661
The FengYun-3 Radio Occultation Sounder GNOS: A Review of the Missions and Early Results Yueqiang Sun, Congliang Liu, Weihua Bai, Yan Liu, Qifei Du, Xianyi Wang, Guanglin Yang, Mi Liao, Zhongdong Yang, Xiaoxin Zhang, Xiangguang Meng, Danyang Zhao, Junming Xia, Yuerong Cai, Gottfried Kirchengast Peer Reviewed	662 - 675

#### **Challenging Navigation Problems 1**

<b>GNSS Expert Witness Evidence in Australian Courts</b>	676 -
Solange Cunin, Andrew Dempster, Allison Kealy, Gary Edmond	690

Position-Domain Hatch Filter for Integrated GPS/BeiDou/Altimeter	691 -
La Woo Kim, Won Jae Yoo, and Hyung Keun Lee	701
<b>NLOS Detection and Compensation using a Vector Tracking-based GPS Software</b>	702 -
Receiver	702 - 712
Bing Xu and Li-Ta Hsu Peer Reviewed	/12
A GNSS Software-Defined Receiver with Vector Tracking Techniques for Land	713 -
Vehicle Navigation	713 -
Yiran Luo, Jian Li, Chunyang Yu, Zhitao Lyu, Zhe Yue, Naser El-Sheimy	121
Direct Estimation of Multipath in a Deep Urban Area using Multi-GNSS Carrier	
Phase Variation and Previous Position	728 -
Yongjun Lee, Byungwoon Park, Yoola Hwang, Byoung-Sun Lee, Jaeyoung Ahn Peer	736
Reviewed	
Range-based 3D Mapping Aided GNSS with NLOS Correction based on Skyplot	737 -
with Building Boundaries	751
Hoi Fung Ng, Guohao Zhang, Li-Ta Hsu Peer Reviewed	751

# Aircraft Navigation and Surveillance

Linear Blend: Data Fusion in the Image Domain for Image-based Aircraft	750
Positioning during Landing Approach	752 - 766
M. Angermann, S. Wolkow, A. Dekiert, U. Bestmann, P. Hecker Peer Reviewed	/00
Model-based Threshold and Centerline Detection for Aircraft Positioning during	767
Landing Approach	767 -
Stephan Wolkow, Maik Angermann, Andreas Dekiert, Ulf Bestmann Peer Reviewed	776
Standards for ARAIM ISM Data Analysis	777
Todd Walter, Juan Blanch, Kazuma Gunning Peer Reviewed	777 - 784
Presentation File	/ 84
SIS Monitoring for ARAIM in the Absence of Precise Clock Estimates	785 -
Kazuma Gunning, Todd Walter, David Powell	801
Development Status of DFMC-SBAS using QZSS PTD (Positioning Technology	
Development) Subsystem	202
Hiroko Tokura, Takayuki Kaneso, Satoru Owada, Takashi Urushido, Mitsunori	802 -
Kitamura Peer Reviewed	806
Presentation File	

# **Ionosphere Monitoring with GNSS**

Assessment and Mitigation of Ionospheric Spatial Decorrelation on GBAS: Lessons	007
Learned	807 - 826
Jiyun Lee	820
<b>Characteristics of Ionospheric Gradients in the Transition Region from Magnetic</b>	827 -
Low to Mid-latitudes for GBAS Implementation	027
M. Nakamura, S. Saito, T. Yoshihara Peer Reviewed	834

Kai Guo Marcio Aquino Sreeja Vadakke Veettil Zhizhao Liji Wij Chen Haroldo	835 - 845
I OPEN U U NANG U OPNENIUS U SAF INDE EL NANNAS, YILU NUNG U NIU PELLY UN U NIU	846 - 853
Xing Meng Attila Komiathy Olga P. Verkhoglyadova, Giorgio Savastano, Mattia	854 - 861

# **Challenging Navigation Problems 2**

<b>Real-time GNSS NLOS Detection and Correction Aided by Sky-Pointing Camera</b>	
and 3D LiDAR	862 -
Xiwei Bai, Weisong Wen, Guohao Zhang, Li-Ta Hsu Peer Reviewed	874
Presentation File	
Hyper-parameter Comparison on Convolutional Neural Network for Visual Aerial	075
Localization	0.0
J. Mark Berhold, Robert C. Leishman, Brett Borghetti, Donald Venable Peer Reviewed	885
Simulated Maritime Magnetic Navigation in the Asia-Pacific Region	886 -
Paul Frontera, Stephen Alessandrini Peer Reviewed	895

# **Aviation Applications of GNSS**

An Overview of Advanced Receiver Autonomous Integrity Monitoring (ARAIM)	896 -
Todd Walter	914
Lower Bounds in Optimal Integrity Monitoring	915 -
Juan Blanch and Todd Walter Peer Reviewed	924
ARAIM with More than two Constellations Yawei Zhai, Xingqun Zhan, Jin Chang, Boris Pervan Presentation File	925 - 941
GNSS Satellite Orbit and Clock Truth Generation for ARAIM Offline Monitoring Jaymin Patel, Samer Khanafseh, Boris Pervan Peer Reviewed Presentation File	942 - 955
Revaluation of Spatial Decorrelation Parameters of Atmospheric Delay for GBAS(Ground-based Augmentation System) Safety DesignTakayuki Yoshihara, Susumu Saito, Atsushi Kezuka, Shinji Saitoh Peer Reviewed	956 - 963
Design and Analysis of a Public Key Infrastructure for SBAS Data Authentication Andrew Neish, Todd Walter, J. David Powell Best Paper Peer Reviewed Presentation File	964 - 988

#### **High Precision GNSS Correction and Monitoring Networks**

Discrepancies Between Provided DCB Estimates and Equivalent Formulations in	200
CAS DCB Product	989 - 996
Harrison Bourne and Jade Morton Peer Reviewed	990
<b>GPS C/A Code Self-Interference: Error Detection Using Existing GBAS Monitors</b> 9	997 -
Jessica A. Belzer, Frank van Graas Peer Reviewed	1012
GPS/BeiDou/Galileo/OZSS Data Over Wide Areas	1013 - 1022
Signal Deformation Monitoring for Anomalous Multipath Threats	1023 -
R. Eric Phelts and Todd Walter Peer Reviewed	1030
Preliminary Test Results of RTK-aided Conical Domain Model for SBAS	
Ionospheric Correction	1031 -
Donguk Kim, Deokhwa Han, Changdon Kee Peer Reviewed	1044
Presentation File	
	1045 - 1054