

# **2023 13th International Conference on Indoor Positioning and Indoor Navigation (IPIN 2023)**

**Nuremberg, Germany  
25 – 28 September 2023**



**IEEE Catalog Number: CFP2309J-POD  
ISBN: 979-8-3503-2012-1**

**Copyright © 2023 by the Institute of Electrical and Electronics Engineers, Inc.  
All Rights Reserved**

*Copyright and Reprint Permissions:* Abstracting is permitted with credit to the source. Libraries are permitted to photocopy beyond the limit of U.S. copyright law for private use of patrons those articles in this volume that carry a code at the bottom of the first page, provided the per-copy fee indicated in the code is paid through Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923.

For other copying, reprint or republication permission, write to IEEE Copyrights Manager, IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08854. All rights reserved.

***\*\*\* This is a print representation of what appears in the IEEE Digital Library. Some format issues inherent in the e-media version may also appear in this print version.***

|                         |                   |
|-------------------------|-------------------|
| IEEE Catalog Number:    | CFP2309J-POD      |
| ISBN (Print-On-Demand): | 979-8-3503-2012-1 |
| ISBN (Online):          | 979-8-3503-2011-4 |
| ISSN:                   | 2162-7347         |

**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  
E-mail: [curran@proceedings.com](mailto:curran@proceedings.com)  
Web: [www.proceedings.com](http://www.proceedings.com)

CURRAN ASSOCIATES INC.  
**proceedings**  
.com

# 2023 13th International Conference on Indoor Positioning and Indoor Navigation (IPIN)

## Table of Contents

Let's Talk about k-NN for Indoor Positioning: Myths and Facts in RF-based Fingerprinting, Joaquín Torres-Sospedra, Cristiano Pendão, Ivo Silva, Filipe Meneses, Darwin Quezada Gaibor, Raul Montoliu, Antonino Crivello, Paolo Barsocchi, Antoni Perez-Navarro and Adriano Moreira...1

A Multimodal Graph Fingerprinting Method for Indoor Positioning Systems, Yinhuan Dong, Tughrul Arslan and Yunjie Yang...7

Flexible K Nearest Neighbors Classifier: Derivation and Application for Ion-mobility Spectrometry-based Indoor Localization, Philipp Müller...13

RANSAC Methods for Robust Positioning with 5G Networks in Industrial IoT Scenarios, Gustav Lindmark, Johannes Nygren and Satyam Dwivedi...19

Overcoming Radio Map Degradation in Wi-Fi-based Positioning Systems, Ivo Silva, Cristiano Pendão, Joaquín Torres-Sospedra and Adriano Moreira...25

Enhanced 5G Sidelink Ranging Based on Carrier Aggregation, Franziska Rasp, Ernst Eberlein, Bastian Perner, Elke Roth-Mandutz and Susanne Hipp...31

Recent Advances in Positioning Technology of GH-LPS in Challenging Environments, Zhijun Meng, Xiaoyu Li, Yufeng Zhang, Kai Liu, Xiye Guo and Jun Yang...37

Applying Carrier Phase to 5G Positioning with Testbed Verification, Yi Wang, Cheng Li, Han Wang and Peiying Zhu...43

Proximity Estimation with BLE RSSI and UWB Range Using Machine Learning Algorithm, Satinath Debnath and Kyle O'Keefe...49

Towards Robust Visual Inertial Odometry in Feature Sparse Structured Environments, Niclas Joswig, Aiden Morrison, Nadeza Sokolova and Laura Ruotsalainen...55

Towards Quality Wi-Fi Synthetic Data for Indoor Positioning Evaluation, Cristiano Pendão, Ivo Silva, Adriano Moreira, Fernando J. Aranda-Polo and Joaquín Torres-Sospedra...63

Optimization of 2D location system for smartphones using a single WiFi access point with Frequency-Scanned Antenna for Real Time Location System, Jose A Lopez Pastor, Miguel Poveda Garcia, Alejandro Gil Martínez, David Cañete Rebenaque and José Luis Gómez-Tornero...69

Smartphone Indoor Positioning using Inertial and Ambient Light Sensors, Masanori Sugimoto, Minoru Suenaga, Hiroki Watanabe, Masanari Nakamura and Hiromichi Hashizume...75

Probabilistic Ray-Tracing Aided Positioning at mmWave frequencies, Vincent Corlay, Viet-Hoa Nguyen, Nicolas Gresset and Cristina Ciochina...81

Fast Calculation Method for Time Difference of Arrival-based Localization, Gyula Simon and Gergely Vakulya...87

A UWB pulse with precursor for ToA measurement, Chris Marshall, Erwin Allebes, Alireza Sheikh, Minyoung Song, Mohieddine El Soussi and Nick Winkel...92

Time-based vs. Fingerprinting-based Positioning Using Artificial Neural Networks, ANIL KIRMAZ, Taylan Sahin, Diomidis Michalopoulos and Wolfgang Gerstaecker...98

Gyro-Free Kalman Filter with Unknown Inputs for SO(3)-based Attitude Estimation, Ghadeer Shaaban, Hassen Fourati, Alain Kibangou and Christophe Prieur...104

Tightly Integrated Motion Classification and State Estimation in Foot-Mounted Navigation Systems, Isaac Skog, Gustaf Hendeby and Manon Kok...110

The Performance of RSS Based Visible Light Positioning Techniques under Different Uniformity Conditions, Jorik De Bruycker, Tom Dhaene and Nobby Stevens...116

Demonstrating the Merits of Integrating Multipath Signals into 5G LoS-Based Positioning Systems for Navigation in Challenging Environments, Qamar Bader, Sharief Saleh, Mohamed Elhabiby and Aboelmagd Noureldin...121

Indoor Positioning using DNN and RF Method Fingerprinting-based on Calibrated Wi-Fi RTT, Lila Rana, Jiabin Dong, Shuyu Cui, Jinlong Li, Jungyu Hwang and Joongoo Park...127

Factor Graph Optimization-based Indoor Pedestrian SLAM with Probabilistic Exact Activity Loop Closures using Smartphone, Shiyu Bai, Weisong Wen, Li-Ta Hsu and Yue Yu...133

Robust Acoustic TOA Estimation based on Multipath Extraction in Frequency Domain, Naizheng Jia, Weimeng Cui, Yuwei Wang, Can Xue, Guangyao Liu, Xinheng Wang, Zuyang Cao and Zhi Wang...141

SIMUL: Synchronized IMU Dataset of Walking People at Six Body Locations, Steffen Kastner, Markus Ebner, Markus Bullmann, Toni Fetzer, Frank Deinzer and Marcin Grzegorzec...148

Machine learning for indoor localization without ground-truth locations, Chanyeong Ju and Jae Hyun Yoo...155

Enhancing Indoor Altitude Estimation on Smartphones: Resolving Ventilation Fan Effects, Kota Tsubouchi, Yuki Hirayama, Takuzo Ikuta and Nobuhiko Nishio...160

Seamless Indoor and Outdoor Positioning with Hybrid Bluetooth AoA and GNSS Signals, Marco Velapatino Gamarra, Stylianos Papaharalabos, Farshid Rezaei, David Bartlett and Peter Karlsson...167

Radio-Frequency Handoff Strategies to Seamlessly Integrate Indoor Localization Systems, Francesco Furfari, Michele Girolami and Paolo Barsocchi...173

A dynamic model switching algorithm for WiFi fingerprinting indoor positioning, Xu Feng, Khuong An Nguyen and Zhiyuan Luo...179

Magneto-Inertial Dead-Reckoning Navigation with Walk Dynamic Model in Indoor Environment, Raphaël Neymann, Alexis Berthou, Jean-François Jourdas, Hugo Lhachemi, Christophe Prieur and Antoine Girard...185

Effect of Non-orthogonality in Dual-axis Gimbal on Rotational Inertial Navigation System, Jaehyuck Cha, Chan Gook Park, Seong Yun Cho, Minsu Jo and Chanju Park...192

Smartphone-Based Multi-Mode Geomagnetic Matching/PDR Integrated Indoor Positioning, Kefan Shao, Zengke Li, Mingcong Shu, Qiang Guo and Qi Wu...197

RETSINA: Reproducibility and Experimentation Testbed for Signal-Strength Indoor Near Analysis, Anna Baskin, Brian T. Nixon, Panos K. Chrysanthis, Christos Laoudias and Constantinos Costa...205

Cooperative Localization Using Received Signal Strength and Least Squares Estimation Methods, Nader Moayeri...211

An empirical multi-wall NLOS ranging model for Wi-Fi RTT indoor positioning, Qing Liang, Guohao Zhang and Li-Ta Hsu...217

A Comparative Study of Gait Analysis Technologies, Luisa Ruiz, Evelyn Alecto, Ana Jimenez Martín, Fernando Seco, Juan Jesus Garcia and Antonio Jimenez Ruiz...223

Calibration-free radiomap construction based on graph map matching, Rory Hughes, Lei Tao, Ilari Vallivaara and Firas Alsehly...229

Comparison of FGO and KF for PDR-GNSS Fusion on Smartphone for Diverse Pedestrian Movements, Amjad Hussain and Luis Enrique Díez...236

Indoor Positioning based on Active Radar Sensing and Passive Reflectors: Reflector Placement Optimization, Sven Hinderer, Pascal Schlachter, Zhibin Yu, Xiaofeng Wu and Bin Yang...242

Ultra-Precise Synchronization for TDoA-based Localization Using Signals of Opportunity, Thomas Maul, Sebastian Klob and Joerg Robert...249

Simulation of machine learning inferences in real-time operating system to improve direction finding in an embedded environment, Nika Nizharadze, Matthias Mahlig and Timon Merk...255

EL-OGISLAM: Escalator Landmark-based Occupancy Grid Inertial SLAM framework, Xiaodong Li, Zhi Xiong, Yan Cui, Yinshou Sun and Yunong Qian...261

A Measurement Platform for the Evaluation of Sparse Acoustic Array Geometries, Georg Fischer, Niklas Thiedecke, Andrea Gabbrielli, Thomas Schaechtle, Fabian Höflinger, Alexander Stolz and Stefan J. Rupitsch...267

Error State Kalman Filter with Implicit Measurement Equations for Position Tracking of a Multi-Sensor System with IMU and LiDAR, Dominik Ernst, Sören Vogel, Ingo Neumann and Hamza Alkhatib...273

Comparative Study of Gaussian Processes, Multi Layer Perceptrons, and Deep Kernel Learning for Indoor Visible Light Positioning Systems, Fan Wu, Nobby Stevens, Lieven De Strycker and Francois Rottenberg...279

LIGHT-PDR: Light Indoor GNSS Carrier Phase Positioning with Machine Learning and Inertial Signal Fusion for Pedestrian Navigation, Ziyou Li, Ni Zhu and Valérie Renaudin...285

RIS-aided Positioning Experiments based on mmWave Indoor Channel Measurements, Moustafa Rahal, Benoît Denis, Taghrid Mazloum, Frederic Munoz and Raffaele D'errico...291

Accurate indoor positioning by combining sensor fusion and obstruction compensation, Jimmy Engström and Jan A. Persson...297

Potentials of Deterministic Radio Propagation Simulation for AI-Enabled Localization and Sensing, Albrecht Michler, Jonas Ninnemann, Jakob Krauthäuser, Paul Schwarzbach and Oliver Michler...304

Impact of CIR processing for UWB radar distance estimation with the DW1000 transceiver, Ben Van Herbruggen, Stijn Luchie, Rafael Berkvens, Jaron Fontaine and Eli De Poorter...310

An LSTM Approach for Modelling Error of Smartphone-reported GNSS Location Under Mixed LOS/NLOS Environments, Yue Yu, Wenzhong Shi, Zhewei Liu, Shiyu Bai, Liang Chen and Ruizhi Chen...317

Low-Cost and Ultra-Precise Synchronization Concept for TDoA Localization of Dairy Cows, Sebastian Klob, Thomas Maul and Joerg Robert...323

Precise Indoor Positioning System for Mobile Robots via Smoothed UWB/IMU Sensor Fusion, Mahmoud Elsanhoury, Jyri Nieminen, Petri Välisuo, Akpojoto Siemuri, Janne Koljonen, Mohammed Salem Elmusrati and Heidi Kuusniemi...329

Ultrasonic Device-Free Localisation System Modelling for Performance Analysis, Alejandro García Requejo, María del Carmen Pérez, Alvaro Hernández, William Wright and Liam Marnane...335

Temporal Stability on Human Activity Recognition based on Wi-Fi CSI, Miguel Matey-Sanz, Joaquín Torres-Sospedra and Adriano Moreira...342

Device-Level and System-Level Autocalibration of Ultra-Wide-Band Localization, Risang Yudanto, Jianqiao Cheng, Erik Hostens, Miel Van der Wilt and Mats Vande Cavey...348

3D millimeter-Wave Indoor Localization, Andrey Sesyuk, Stelios Ioannou and Marios Raspopoulos...355

Pose Graph Optimization for a MAV Indoor Localization Fusing 5GNR TOA with an IMU, Meisam Kabiri, Claudio Cimorelli, Hriday Bavle, Jose Luis Sanchez-Lopez and Holger Voos...362

Indoor Positioning Methods Based on Dual Feet-Mounted IMUs With Distance Constraints, Xiaofeng Ma and Simo Särkkä...368

Study on a Visible Light Communication and Positioning System Utilizing an Optical Diffusion Filter and Rolling Shutter Sensor, Reo Okawara, Tadashi Ebihara, Naoto Wakatsuki, Keiichi Zempo and Koichi Mizutani...374

Understanding and Using Spatial Landmarks of Visually Impaired People for Navigation Applications, Min Wang, Ni Zhu, Valérie Renaudin, Aurelie Dommès and Myriam Servieres...380

Uncertainty-based Fingerprinting Model Selection for Radio Localization, Maximilian Stahlke, Tobias Feigl, Sebastian Kram, Bjoern M. Eskofier and Christopher Mutschler...386

Multipath Delay Estimation in Complex Environments using Transformer, Jonathan Ott, Maximilian Stahlke, Sebastian Kram, Tobias Feigl and Christopher Mutschler...392

Millimetre Wave Radar System for Safe Flight of Drones in Human-Transited Environments, Felipe Parralejo, José A. Paredes, Fernando J. Aranda-Polo, Fernando J. Álvarez Franco and Josan Moreno...398

Centralized Optical 3D Positioning System for Emitting Tags, Elena Aparicio-Esteve, Jesús Ureña, Álvaro Hernández, David Moltó, José M. Villadangos and Miguel Cubero...404

Anchor Layout Optimization for Ultrasonic Indoor Positioning Using Swarm Intelligence, Daan Delabie, Thomas Wilding, Liesbet Van der Perre and Lieven De Strycker...410

FTM-Broadcast: Efficient Network-wide Ranging, Yann Busnel and Hervé Rivano...416

Investigating the Impact of Outfits on AI-Based Pedestrian Dead Reckoning with a Wearable Inertial Sensor Placed in the Pocket, Hanyuan FU, Valérie Renaudin, Thomas Bonis and Ni Zhu...422

Indoor 3D Positioning Method for a Microphone using a Single Speaker, Masanari Nakamura, Yuta Funada, Hiroaki Murakami, Hiromichi Hashizume and Masanori Sugimoto...428

Alternative Approach to Integrate GNSS Doppler in Kalman Filter for Smartphone Positioning, Naman Agarwal, Kyle O'Keefe and Richard Klukas...434

Asynchronous time-based architecture proposal for the positioning of UAVs for indoor TV filming, Javier Díez-González, Paula Verde, Rubén Ferrero-Guillén, Alberto Martínez-Gutiérrez, Rubén Álvarez, Hilde Perez and Joaquín Torres-Sospedra...440

UJI Probes: Dataset of Wi-Fi Probe Requests, Tomas Bravenec, Joaquín Torres-Sospedra, Michael Gould and Tomas Fryza...446

Deep Learning based Positioning with Beamformed CSI Fingerprints, Anastasios Foliadis, Mario H. Castañeda Garcia, Richard A. Stirling-Gallacher, Xitao Gong and Reiner S. Thomä...452

A Novel Differential Phase of Arrival-based Experimental Visible Light Positioning System, Yuanyuan Xu, Zixuan Ling, Jianeng Mei, Yuhao Wang, Xiaodong Liu, Zhenghai Wang and Xun Zhang...458

A Novel Experimental Visible Light Positioning System with Low Bandwidth Requirement and High Precision Pulse Reconstruction, Xuan Huang, Xueming Pan, Zhixin Wan, Mengzhen Xu, Zhenghai Wang, Xiaodong Liu, Yuhao Wang, and Xun Zhang...464

Magnetic Field-based Indoor Localization of a Tracked Robot with Simultaneous Calibration, Benjamin Siebler, Tim Gerstewitz, Stephan Sand and Uwe D. Hanebeck...470

Data-driven simulation of wireless communication signal strength in indoor environments, Takuhiro Shimokawa, Kota Tsubouchi, Yoshihiro YK Kawahara, Hiroaki HM Murakami and Masamichi MS Shimosaka...476

UWB-based Positioning System for Indoor Sports, Adrián Juárez, Sergio Fortes, Elizabeth Colin, Carlos Baena, Eduardo Baena and Raquel Barco...482

Fingerprint-based fusion of magnetic field data with multiple wireless technologies for indoor mobile robot positioning, Peter Sarcevic, Dominik Csik, Richard Pesti, Massimo Stefanoni, József Sárosi and Ákos Odry...488

Step Length Is a More Reliable Measurement Than Walking Speed for Pedestrian Dead-Reckoning, Fatemeh Elyasi and Roberto Manduchi...494

Close-Range Indoor Proximity Detection for COVID-19 Exposure Notifications Using Smartphone Magnetometer Traces, Zach Van Hyfte and Avidah Zakhor...500

Unsupervised Analysis of Daily Routine Evolution for Elderly People Using Room-Level Localisation, Sergio Lluva-Plaza, Joaquín Torres-Sospedra, Juan Jesus Garcia, Jose Manuel Villadangos and Ana Jimenez Martín...506

FMCW Based Positioning Using Multiple SHF RFID Transponders, Sebastian Böller, Thorben Greuter and Anton Grabmaier...512

Server based Bluetooth Low Energy (BLE) Positioning using Received Signal Strength (RSS) Measurements, Christian Gentner, Philipp Hager and Markus Ulmschneider...517

RSS Channel-Based Integration for BLE Fingerprinting Positioning, Fernando J. Aranda-Polo, Felipe Parralejo, Teodoro Aguilera Benítez, Fernando J. Álvarez Franco and Joaquín Torres-Sospedra...524

Crowdsourced Wi-Fi Access Point Localization using Vertical Movement Detection, HyeonSeon An, Hayoung Gu, Sumin Joo and Jeongsik Choi...530

Semi-Unsupervised Mitigation of Human Body Shadowing for Indoor UWB pedestrian tracking,  
Cedric De Cock, Emmeric Tanghe, Wout Joseph and David Plets...536

UnSpoof: Distance Spoofing-Evident Localization Using UWB, Haige Chen and Ashutosh Dhekne...543