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EDITORIAL

WILEY ION

Navigator Notes

Editorial Highlights from the Editor-in-Chief

Welcome to the Winter 2020 issue of *NAVIGATION*. As the special platinum cover of this edition of *NAVIGATION* announces, this year proudly marks the 75th anniversary of The Institute of Navigation (ION), a milestone that is significant in light of the remarkable changes we have seen in the science, engineering and art of positioning, navigation and timing or PNT. It was at the ION's first annual meeting in October 1945 in New York City that a recommendation was made that the Institute publish a journal, to be called "NAVIGATION." The initial editorial board would consist of the editor, Elizabeth Sternberg Mulders; the managing editor, Major John W. Calvert; and the assistant editor, E.F. Poulsen. Manuscripts had to be typewritten, double-spaced, and the original and a carbon copy had to be submitted to the managing editor. Manuscripts could be illustrated but only a limited number of halftones or zinc etchings would be furnished if satisfactory photographs or drawings were supplied by the author. Production techniques have certainly changed over the past 75 years.

The first issue was published in March 1946 and that issue contained three papers: "The Arctic Flights of the Lancaster 'Aries,' May 1945," "Radar Applications to Aerology," and "LORAN." It also featured a review of *Tables for the Determination of Lines of Position of a Ship by Radio Bearings* published in the Soviet Union (in Russian); "Noon Interval Tables" (information for more conveniently determining the meridian altitude of the sun from a vessel under way); "Notes from the New York Meeting;" and "Letters to the Editor." This first issue of *NAVIGATION* and the subsequent issues down through the years are available from the ION website. The journal is a remarkable resource on the history of navigation over the past 75 years.

Below, we introduce a new initiative by The Institute of Navigation: video abstracts. Authors are now able to submit a short (1-3 minutes) video introducing their research. This allows authors to broaden their audience and increase citation counts. We'd like to especially thank Dr. Li-Ta Hsu for being the first to submit a video abstract. ION has enjoyed all the videos received thus far and will continue to promote video abstracts on its website, on social media platforms and at conferences.

VIDEO ABSTRACTS

Video Abstracts allow authors to present their research in their own words. This multimedia format communicates the background and context of authors' research in a quick and easy way, elevating research from simple print delivery.

Video for "Resilient Multipath Prediction and Detection Architecture for Low-Cost Navigation in Challenging Urban Areas"
By Ivan Smolyakov
(https://www.ion.org/publications/abstract.cfm?articleID=102862)

Abstract: A twofold architecture based on GNSS multipath environment prediction and detection is presented in a context of loosely coupled and tightly coupled IMU/GNSS integration for navigation in urban areas. A signal quality monitoring group of techniques is applied for a platform self-contained effort to detect and exclude multipath-contaminated GNSS signals. Additionally, the sensor integration Kalman filter stochastic model is adjusted on-the-fly based on a GNSS multipath environment map. The map is populated by crowdsourcing and contains the spatial distribution of average carrier-to-noise-density ratio measurements, linked to the probability of non-line-of-sight, multipath-contaminated, diffracted, and attenuated signal reception. To address the map availability issue, a random forest machine learning model is developed to propagate the map to the city areas not directly surveyed by the mapping fleet based on open-access geographic data. The architecture performance is evaluated in the automotive scenario showing 13–17% accuracy improvement compared to a conventional Kalman filter.

Article Citation: Smolyakov, I, Rezaee, M, Langley, RB. Resilient multipath prediction and detection architecture

for low-cost navigation in challenging urban areas. *NAVIGATION*. 2020; 67: 397–409. https://doi.org/10.1002/navi.362

Video for "Integrity Monitoring of Graph-SLAM Using GPS and Fish-Eye Camera"
By Sriramya Bhamidipati
(https://www.ion.org/publications/abstract.cfm?articleID=102872)

Abstract: We propose a Simultaneous Localization and Mapping (SLAM)-based Integrity Monitoring (IM) algorithm using GPS and fish-eye camera to compute the protection levels while accounting for multiple faults in GPS and vision. We perform graph optimization using GPS pseudoranges, pixel intensities, vehicle dynamics, and satellite ephemeris to simultaneously localize the vehicle, GPS satellites, and key image pixels in the world frame. We estimate the fault mode vector by analyzing the temporal correlation across pseudorange residuals and spatial correlation across pixel intensity residuals. To isolate the vision faults, we develop a superpixel-based piecewise random sample consensus. For the estimated fault mode, we compute the protection levels by performing worst-case failure slope analysis on the batch realization of linearized Graph-SLAM formulation. We perform real-world experiments in an alleyway in Stanford, California and a semi-urban area in Champaign, Illinois. We demonstrate higher localization accuracy and tighter protection levels as compared to GPS-only SLAM-based IM.

Article Citation: Bhamidipati, S, Gao, GX. Integrity monitoring of Graph-SLAM using GPS and fish-eye camera. *NAVIGATION*. 2020; 67: 583–600. https://doi.org/10.1002/navi.381

Video for "High-Precision Unambiguous Tracking Technique for BDS B1 Wideband Composite Signal"
By Zheng Yao
(https://www.ion.org/publications/abstract.cfm?articleID=102875)

Abstract: In the BeiDou Navigation Satellite System (BDS) B1 band, a single-sideband complex binary offset carrier (SCBOC) modulation is employed to combine the legacy and the modernized B1 signals into an asymmetric-wideband composite signal for the backward compatibility. However, SCBOC modulation has only been regarded as a means to achieve the co-existence between B1I and B1C signals, whose high-precision ranging potential is not fully understood or exploited. In this paper, a new pathway for BDS B1 receivers to further enhance their ranging precision is established for the first time, by proposing an unambiguous cross-assisted tracking (CAT) loop, which fully exploits the ranging performance of the SCBOC subcarrier and the inherent coherence between components in the composite signal. Simulation and experiment using live BDS-3 signals show that compared to the traditional tracking processing for independent components, the CAT loop can significantly improve ranging performance precision, thus providing a high-precision processing mode for the BDS B1 composite signal.

Article Citation: Gao, Y, Yao, Z, Lu, M. High-precision unambiguous tracking technique for BDS B1 wideband composite signal. *NAVIGATION*. 2020; 67: 633–650. https://doi.org/10.1002/navi.377

Video for "Correcting NLOS by 3D LiDAR and Building Height to Improve GNSS Single Point Positioning"
By Dr. Li-Ta Hsu
(https://www.ion.org/publications/abstract.cfm?articleID=102828)

Abstract: We present a novel method to detect the GNSS NLOS and correct the NLOS pseudorange measurements based on on-board sensing. This paper demonstrates the use of LiDAR scanner and a list of building heights to describe the perceived environment. To estimate the geometry and pose of the top edges of buildings (TEBs) relative to the GNSS receiver, a surface segmentation method is employed to detect the TEBs of surrounding buildings using 3D LiDAR point clouds. The top edges of the building are extracted and extended using the building height list in Skyplot to identify the NLOS-affected ones. Innovatively, the NLOS delay in pseudorange is corrected based on the detected TEBs. Weighted least squares (WLS) is used to cooperate the corrected NLOS and other pseudorange measurements. Vehicle experiments are conducted in two different urban canyons to verify the effectiveness of the proposed method in improving GNSS single point positioning (SPP) accuracy.

Article Citation: Wen, W, Zhang, G, Hsu, L.-T. Correcting NLOS by 3D LiDAR and building height to improve GNSS single point positioning. *NAVIGATION*. 2019; 66: 705–718. https://doi.org/10.1002/navi.335

WEBINARS

ION Webinars highlight timely and engaging papers published in *NAVIGATION* on topics of interest to the PNT community in an interactive virtual presentation.

October 22, 2020 Webinar: Relative Navigation of Fixed-Wing Aircraft in GPS-Denied Environments
By Dr. Kevin Brink

(https://www.ion.org/publications/webinar-brink.cfm)

Abstract: This work enables GPS-denied flight on fixed-wing UAS by accounting for fixed-wing-specific sensing requirements and using a methodology called relative navigation as an overarching framework. The development of an odometry-like, front-end, EKF-based estimator that utilizes only a monocular camera and an inertial measurement unit (IMU) is presented. The filter uses the measurement model of the multi-state-constraint Kalman filter. The filter also regularly resets its origin in coordination with the declaration of keyframe images. The keyframe-to-keyframe odometry estimates and their covariances are sent to a global back end that represents the global state as a pose graph. The back end is better suited to represent nonlinear uncertainties and incorporate opportunistic global constraints. We also introduce a method to account for front-end velocity bias in the back-end optimization. The paper provides simulation and hardware flight-test results of the front-end estimator and performs several back-end optimizations on the front-end data. (https://www.ion.org/publications/abstract.cfm?articleID=102853)

Article Citation: Ellingson, G, Brink, K, McLain, T. Relative navigation of fixed-wing aircraft in GPS-denied environments. *NAVIGATION*. 2020; 67: 255–273. https://doi.org/10.1002/navi.364

August 20, 2020 Webinar: Multi-Constellation ARAIM Exploiting Satellite Motion
By Dr. Mathieu Joerger

(https://www.ion.org/publications/webinar-joerger.cfm)

Abstract: In this work, a new time-sequential positioning and fault detection method is developed for dual-frequency, multi-constellation Advanced Receiver Autonomous Integrity Monitoring (ARAIM). Unlike conventional "snapshot" ARAIM, sequential ARAIM exploits changes in satellite geometry at the cost of slightly higher computation and memory loads. From the perspective of users on Earth, the motion of any given GNSS satellite is small over short time intervals. But the accumulated geometry variations of redundant satellites from multiple GNSS can be substantial. This paper quantifies performance benefits brought by satellite motion to ARAIM. It specifically addresses the following challenges: (a) defining raw GNSS code and carrier error models over time, (b) designing estimators and fault detectors exploiting geometric diversity for positioning, cycle ambiguity estimation, and integrity evaluation, and (c) formulating these algorithms in a computationally efficient implementation. Performance improvements provided by sequential ARAIM over snapshot ARAIM are evaluated by worldwide availability analysis for aircraft approach navigation. (https://www.ion.org/publications/abstract.cfm?articleID=102852)

Article Citation: Joerger, M, Pervan, B. Multi-constellation ARAIM exploiting satellite motion. *NAVIGATION*. 2020; 67: 235–253. https://doi.org/10.1002/navi.334

Dr. Richard B. Langley