Received: 11 May 2022 | Revised: 11 May 2022 | Accepted: 16 May 2022

DOI: 10.33012/navi.525

EDITORIAL

Navigator Notes

Editorial Highlights from the Editor-in-Chief

Dr. Richard B. Langley
Editor of *NAVIGATION: Journal of the Institute of Navigation*
Email: lang@unb.ca

Welcome to the Summer 2022 issue of *NAVIGATION* – our second issue since transitioning to an open access journal at the beginning of the year. We have a new dedicated website for our journal: https://navi.ion.org/. From the home page, you can find the current issue, early view articles to be compiled into the next issue, recent archived issues, and other information about the journal. The full archive of *NAVIGATION* is available on the ION website: https://www.ion.org/publications/browse.cfm.

Interest in *NAVIGATION* articles as evidenced by the number of downloads continues to grow. Below, we present a report on recent downloads including a list of the top 10 downloaded articles in 2021.

NAVIGATION has an extraordinary group of associate editors—each one a leading expert in their field—who selflessly help to make our journal exceptional. We welcome with gratitude five new associate editors who have joined the editorial board this year:
Dr. Santiago Perea Diaz, European Space Agency; Dr. Li-Ta Hsu, The Hong Kong Polytechnic University; Dr. Y. Jade Morton, University of Colorado, Boulder; Dr. Fabian Rothmaier, Airbus Defence and Space; and Dr. Zhe "Jenny" Yang, Tongji University. The full list of editorial board members can be found on the *NAVIGATION* website.

In this issue, we again feature articles on a wide range of topics including space navigation, 3D-mapping-aided navigation, and gravity modeling in GNSS-aided inertial navigation. We are also featuring an invited review article on the integrity of visual navigation.

ION will continue promoting the research of journal authors through video abstracts hosted on the ION website. In fact, a video abstract is now compulsory for publishing in *NAVIGATION*. The latest video abstracts are documented below. ION also engages with the PNT community, through its webinar series, to highlight current topics of interest to the community. The most recent webinars are also documented below.

TOP DOWNLOADED ARTICLES FROM 2021

Downloads of *NAVIGATION* articles increased 7.5% in 2021. China was the top consumer of content at at 32%, USA came second at 24%, Germany third at 7%, and South Korea fourth at 5%. Google Search and Google Scholar continue to be

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2022 Institute of Navigation

the top referral source for *NAVIGATION* content. Here are the top ten downloaded manuscripts in 2021:

Montenbruck O, Steigenberger P, Aicher M. A long-term broadcast ephemeris model for extended operation of GNSS satellites. *NAVIGATION*. 2021; *68*(1): 199–215. https://doi.org/10.1002/navi.404

Borio D, Gioia C. GNSS interference mitigation: A measurement and position domain assessment. *NAVIGATION*. 2021; *68*(1): 93–114. https://doi.org/10.1002/navi.391

Hauschild A, Montenbruck O. Precise real-time navigation of LEO satellites using GNSS broadcast ephemerides. *NAVIGATION*. 2021; *68*(2): 419–432. https://doi.org/10.1002/navi.416

Gunawardena S, Pany T, Curran J. ION GNSS software-defined radio metadata standard. *NAVIGATION*. 2021; *68*(1): 11–20. https://doi.org/10.1002/navi.407

Zhang G, Hsu L-T. Performance assessment of GNSS diffraction models in urban areas. *NAVIGATION*. 2021; *68*(2): 369–389. https://doi.org/10.1002/navi.417

Rothmaier F, Chen Y-H, Lo S, Walter T. GNSS spoofing detection through spatial processing. *NAVIGATION*. 2021; *68*(2): 243–258. https://doi.org/10.1002/navi.420

Wang P, Morton YJ. Performance comparison of time-of-arrival estimation techniques for LTE signals in realistic multipath propagation channels. *NAVIGATION*. 2020; *67*(4): 691–712. https://doi.org/10.1002/navi.395

Caamano M, Juan JM, Felux M, Gerbeth D, González-Casado G, Sanz J. Network-based ionospheric gradient monitoring to support GBAS. *NAVIGATION*. 2021; *68*(1): 135–156. https://doi.org/10.1002/navi.411

Wen W, Pfeifer T, Bai X, Hsu L-T. Factor graph optimization for GNSS/INS integration: A comparison with the extended Kalman filter. *NAVIGATION*, 2021; *68*(2): 315–331. https://doi.org/10.1002/navi.421

Zhou N, Lau L, Bai R, Moore T. Novel prior position determination approaches in particle filter for ultra wideband (UWB)-based indoor positioning. *NAVIGATION*. 2021; *68*(2): 277–292. https://doi.org/10.1002/navi.415

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 "Improved Automatic Detection of GPS Satellite Oscillator Anomaly using a Machine-Learning Algorithm"
By Yunxiang Liu and Y. Jade Morton
(https://www.ion.org/publications/abstract.cfm?articleID=102940)

Abstract: This paper presents a random-forest-based machine-learning algorithm to automatically detect satellite oscillator anomalies using dual- or triple-frequency GPS carrier-phase measurements. The algorithm can distinguish satellite oscillator anomalies from other GPS carrier-phase disturbances including ionospheric scintillation and receiver oscillator anomalies. Carrier-phase power spectral density and carrier-phase ratios between carriers are extracted from measurements and applied as input features to the random-forest algorithm. The method is trained using data collected at seven GNSS monitoring stations located in Alaska, Ascension Island, Greenland, Hong Kong, Peru, Puerto Rico, and Singapore. The overall detection accuracies of 98.4% and 99.0% were achieved for dual- and triple-frequency signals, respectively. The method outperforms other machine-learning algorithms. The preliminary detection results demonstrate that the method presented can be employed on a global satellite oscillator anomaly monitoring system.

Article Citation: Liu, Y., & Morton, Y. J. (2022). Improved automatic detection of GPS satellite oscillator anomaly using a machine-learning algorithm. *NAVIGATION*, *69*(1). https://www.doi.org/10.33012/navi.500

Video for "High-Precision Vision Localization System for Autonomous Guided Vehicles in Dusty Industrial Environments"
By Xingjie Liu, Guolei Wang, and Ken Chen
(https://www.ion.org/publications/abstract.cfm?articleID=102941)

Abstract: Ensuring a convenient yet accurate localization solution is an essential problem in wireless-denied industrial scenarios. Therefore, in this study, a vision localization system with light emitting diode (LED) array targets for autonomous guided vehicle (AGV) navigation is proposed. The visible targets were calibrated and the pose was computed using a camera that viewed the LED target. A novel data filtering method that integrated the odometer data and inertial measurement unit (IMU) data with vision data was introduced to provide stable and accurate localization. The vision localization system was tested on a 5-m-long AGV and the results demonstrated that the proposed system obtained a static position accuracy at 6 mm, kinematic position accuracy at 10 mm, and angle accuracy at 0.052°, which is more precise than other methods used in industrial AGV applications.

Article Citation: Liu, X., Wang, G., & Chen, K. (2022). High-precision vision localization system for autonomous guided vehicles in dusty industrial environments. *NAVIGATION*, *69*(1). https://doi.org/10.33012/navi.502

Video for "On Enhanced PPP with Single Difference Between-Satellite Ionospheric Constraints"
By Yan Xiang, Xin Chen, Ling Pei, Yiran Luo, Yang Gao, and Wenxian Yu
(https://www.ion.org/publications/abstract.cfm?articleID=102942)

Abstract: Applications of precise point positioning (PPP) are limited by PPP's long convergence time. One effective way to shorten the convergence time is to apply ionospheric constraints because of the external ionospheric information. The conventional way to do this is to apply high precision but biased ionospheric corrections. The limitations of the method are that all ionospheric constraints must be derived from the same set of reference stations to have the same data. An approach based on single differences between satellite ionospheric constraints (SDBS-IONO) was developed to address the data issue due to having no common satellite visibility.

The proposed method is more flexible and scalable in terms of adding ionospheric constraints. Based on a network of about 130 stations, we validated the proposed SDBS-ION method and compared it to the conventional method. Our results confirmed that the ionospheric constraints enhance the PPP convergence time significantly depending on the accuracy of ionospheric constraints. Finally, we discuss crucial factors regarding how long and accurate the effectiveness of ionospheric constraints are in reducing PPP convergence time.

Article Citation: Xiang, Y., Chen, X., Pei, L., Luo, Y., Gao, Y., & Yu, W. (2022). On enhanced PPP with single difference between-satellite ionospheric constraints. *NAVIGATION*, *69*(1). https://doi.org/10.33012/navi.505

Video for "Robust GPS-Vision Localization via Integrity-Driven Landmark Attention"
By Sriramya Bhamidipati and Grace Gao
(https://www.ion.org/publications/abstract.cfm?articleID=102943)

Abstract: For robust GPS-vision navigation in urban areas, we proposed an integrity-driven landmark attention (ILA) technique via stochastic reachability. Inspired by cognitive attention in humans, we performed convex optimization to select a subset of landmarks from GPS and vision measurements that maximized integrity-driven performance. Given known measurement error bounds in non-faulty conditions, our ILA technique follows a unified approach to address both GPS and vision faults and is compatible with any off-the-shelf estimator. We analyze measurement deviation to estimate the stochastic reachable set of positions associated with each landmark, which is parameterized via probabilistic zonotope (p-zonotope). We apply set union to formulate a p-zonotopic cost that represents the size of position bounds based on landmark inclusion/exclusion. We jointly minimize the p-zonotopic cost and maximize the number of landmarks via convex relaxation. For an urban data set, we demonstrated improved localization accuracy and robust predicted availability for a pre-defined risk and alert limit.

Article Citation: Bhamidipati, S., & Gao, G. (2022). Robust GPS-vision localization via integrity-driven landmark attention. *NAVIGATION*, *69*(1). https://doi.org/10.33012/navi.501

Video for "Multi-Objective Design of a Lunar GNSS"
By Filipe Pereira, Patrick M. Reed, and Daniel Selva
(https://www.ion.org/publications/abstract.cfm?articleID=102944)

Abstract: The success of future lunar missions depends on quality positioning, navigation, and timing (PNT) information. Earthbound GNSS signals can be received at lunar distances but suffer from poor geometric dilution of precision (GDOP) and provide no coverage of the lunar far side. This article explores the design space of a dedicated GNSS system in lunar orbit by using a multi-objective evolutionary algorithm framework to optimize GDOP, availability, space segment cost, station-keeping ΔV, and robustness to single-satellite failure. Results show that Pareto approximate solutions that achieve a global GDOP availability (GDOP = 6.0) greater than 98% contain a minimum of 24 satellites in near-circular polar orbits at an altitude of ~2 lunar radii. The impact of single-satellite failure on GDOP outage is analyzed and a no-maneuver scenario is considered. Design rules characterizing

optimal solutions are identified and trade-offs between station-keeping maneuver frequency, performance, and design lifetime are discussed.

Article Citation: Pereira, F., Reed, P. M., & Selva, D. (2022). Multi-objective design of a lunar GNSS. *NAVIGATION*, *69*(1). https://doi.org/10.33012/navi.504

Video for "Designing Low-Correlation GPS Spreading Codes with a Natural Evolution Strategy Machine-Learning Algorithm"
By Tara Yasmin Mina and Grace Xingxin Gao
(https://www.ion.org/publications/abstract.cfm?articleID=102945)

Abstract: With the birth of the next-generation GPS III constellation and the upcoming launch of the Navigation Technology Satellite-3 (NTS-3) testing platform to explore future technologies for GPS, we are indeed entering a new era of satellite navigation. Correspondingly, it is time to revisit the design methods of the GPS spreading code families. In this work, we develop a natural evolution strategy (NES) machine-learning algorithm with a Gaussian proposal distribution which constructs high-quality families of spreading code sequences. We minimize the maximum between the mean-squared auto-correlation and the mean-squared cross-correlation and demonstrate the ability of our algorithm to achieve better performance than well-chosen families of equal-length Gold codes and Weil codes, for sequences of up to length-1023 and length-1031 bits and family sizes of up to 31 codes. Furthermore, we compare our algorithm with an analogous genetic algorithm implementation assigned the same code evaluation metric. To the best of the authors' knowledge, this is the first work to explore using a machine-learning approach for designing navigation spreading code sequences.

Article Citation: Mina, T. Y., & Gao, G. X. (2022). Designing low-correlation GPS spreading codes with a natural evolution strategy machine-learning algorithm. *NAVIGATION*, *69*(1). https://doi.org/10.33012/navi.506

Video for "Results on GNSS Spoofing Mitigation Using Multiple Receivers"
By Niklas Stenberg, Erik Axell, Jouni Rantakokko, and Gustaf Hendeby
(https://www.ion.org/publications/abstract.cfm?articleID=102947)

Abstract: GNSS receivers are vulnerable to spoofing attacks in which false satellite signals deceive receivers to compute false position and/or time estimates. This work derives and evaluates algorithms that perform spoofing mitigation by utilizing double differences of pseudorange or carrier-phase measurements from multiple receivers. The algorithms identify pseudorange and carrier-phase measurements originating from spoofing signals, and omit these from the position and time computation. The algorithms are evaluated with simulated and live-sky meaconing attacks. The simulated spoofing attacks show that mitigation using pseudoranges is possible in these tests when the receivers are separated by five meters or more. At 20 meters, the pseudorange algorithm correctly authenticates six out of seven pseudoranges within 30 seconds in the same simulator tests. Using carrier phase allows mitigation with shorter distances between receivers, but requires better time synchronization between the receivers. Evaluations with live-sky meaconing attacks show the validity of the proposed mitigation algorithms.

Article Citation: Stenberg, N., Axell, E., Rantakokko, J., & Hendeby, G. (2022). Results on GNSS spoofing mitigation using multiple receivers. *NAVIGATION*, *69*(1). https://doi.org/10.33012/navi.510

Video for "Coherent Combining and Long Coherent Integration for BOC Signal Acquisition under Strong Interference"
By Chun Yang, Andrey Soloviev, Ananth Vadlamani, and Joung C. Ha
(https://www.ion.org/publications/abstract.cfm?articleID=102948)

Abstract: A coherent combining and long coherent integration (CCLCI) scheme is presented for standalone direct acquisition of binary offset carrier (BOC) signals under strong radio frequency interference (RFI). To mitigate the ambiguity of BOC signals, a split-spectrum method extracts the upper and lower sidebands of a BOC signal, treats them separately as two binary phase shift keying (BPSK) signals, and finally combines the results to recover the loss due to splitting. The CCLCI scheme burns through strong interference by building up the desired weak signal while averaging out noise and interference. It exploits all information available (L1 and L2, upper and lower sidebands, odd and even chips, and I- and Q-components) by applying coherent combining across signal components and long coherent integration over time, followed by noncoherent accumulation if necessary. Issues and enabling techniques are described. The results of an embedded implementation in demonstration with a GPS RF simulator are analyzed.

Article Citation: Yang, C., Soloviev, A., Vadlamani, A., & Ha, J. C. (2022). Coherent combining and long coherent integration for BOC signal acquisition under strong interference. *NAVIGATION*, *69*(1). https://doi.org/10.33012/navi.508

Video for "Detecting Slowly Accumulating Faults Using a Bank of Cumulative Innovations Monitors in Kalman Filters"
By John D. Quartararo and Steven E. Langel
(https://www.ion.org/publications/abstract.cfm?articleID=102949)

Abstract: Extended Kalman filters (EKFs) that monitor innovations over time have been demonstrated to be effective at detecting slowly accumulating measurement faults (Quartararo & Langel, 2020; Tanil et al., 2018). This paper first demonstrates that a single cumulative monitor becomes increasingly sensitive to measurement error model uncertainty as the accumulation interval increases, leading to false alarm and detection rates that can differ significantly from predefined design parameters. In response, a bank of finite-length cumulative innovations monitors is explored for fault detection in multisensor navigation systems. A novel extension to traditional covariance analysis (Covariance Analysis Including Expected Values or CAIEV) is developed to accommodate measurement faults and is used in addition to Monte Carlo simulations to present detection results for a variety of GPS fault profiles and inertial measurement unit (IMU) grades. Data for time-to-detect is presented alongside the position-domain bias induced by the fault at the time of detection. We show that the monitor bank can reliably detect the presence of faulty measurements after the position-domain bias has reached only tens of meters using tactical and aviation-grade IMUs for the cases considered, an improvement over other innovations-based techniques.

Article Citation: Quartararo, J. D., & Langel, S. E. (2022). Detecting slowly accumulating faults using a bank of cumulative innovations monitors in Kalman filters. *NAVIGATION*, *69*(1). https://doi.org/10.33012/navi.507

Video for "WAAS and the Ionosphere – A Historical Perspective: Monitoring Storms"
By Lawrence Sparks, Eric Altshuler, Nitin Pandya, Juan Blanch, and Todd Walter
(https://www.ion.org/publications/abstract.cfm?articleID=102950)

Abstract: Satellite-based augmentation systems ensure the accuracy and integrity of aircraft position estimates derived from radio signals broadcast by the Global Navigation Satellite System. The United States' Wide Area Augmentation System (WAAS) protects users of the Global Positioning System from threats generated by ionospheric disturbances. The means by which WAAS mitigates these threats depends upon their magnitude. This paper addresses: a) how WAAS monitors the level of ionospheric perturbation over North America; b) how various availability and integrity concerns have influenced the implementation of WAAS's extreme and moderate ionospheric storm detectors; c) how the algorithms governing these implementations have evolved since WAAS's commissioning in 2003; and d) how the largest ionospheric storms of the past two solar cycles can be ranked according to their impact on WAAS. A subsequent companion paper will address the evolution of the WAAS methodology for protecting users from the adverse influence of more moderate ionospheric disturbances.

Article Citation: Sparks, L., Altshuler, E., Pandya, N., Blanch, J., & Walter, T. (2022). WAAS and the ionosphere – a historical perspective: Monitoring storms. *NAVIGATION*, *69*(1). https://doi.org/10.33012/navi.503

Video for "A Station-Specific Ionospheric Modeling Method for the Estimation and Analysis of BeiDou-3 Differential Code Bias Parameters"
By Ningbo Wang, Zishen Li, Andrzej Krankowski, and Xingliang Huo
(https://www.ion.org/publications/abstract.cfm?articleID=102951)

Abstract: A modified generalized trigonometric series (GTS) function is presented for the joint estimation of local ionospheric activities and differential code biases (DCBs) of the third-generation BeiDou navigation satellite system (BeiDou-3). Using observational data from the iGMAS and IGS-MGEX networks, DCBs between the pilot-, data- and I-components of BeiDou-3 signals are estimated and analyzed for January 2019. The stability of the modified GTS-based satellite DCB estimates an improvement of about 29.7% compared to the original GTS-based results. In comparison with transmitted TGDB1Cp and TGDB2ap parameters, the consistency between broadcast and post-processed biases reaches 0.33 and 0.50 ns. The estimated data-pilot biases are observed to be notably smaller than BeiDou-3 transmitted inter-signal correction (ISC) parameters. In the analysis of receiver B1I-B3I, DCBs generated from the independent BeiDou-2 and BeiDou-3 constellations, the receiver-type dependent biases are emphasized, which raises the consideration of using receiver-group specific bias concept in the future estimation of BeiDou DCBs.

Article Citation: Wang, N., Li, Z., Krankowski, A., & Huo, X. (2022). A station-specific ionospheric modeling method for the estimation and analysis of BeiDou-3 differential code bias parameters. *NAVIGATION*, *69*(1). https://doi.org/10.33012/navi.509

Video for "A Flexible GNSS Spoofer Localization System: Spoofing Discrimination and Localization Method"
By Jian Wen, Hong Li, and Mingquan Lu
(https://www.ion.org/publications/abstract.cfm?articleID=102952)

Abstract: Global navigation satellite systems (GNSS) are vulnerable to spoofing attacks. To shut down a spoofer, it is necessary to locate the spoofer first. Many spoofer localization systems use long cables for the synchronization of multiple receivers. However, a flexible spoofer localization system free from cables is sometimes essential so the receivers can move freely and are flexible to deploy. This paper solves two major problems in developing such a system: spoofing discrimination without requiring synchronization and having an effective method using asynchronous raw measurements with no other assistance. First, this paper proposes to use the extended pseudorange double-difference method to discriminate spoofing signals. The performance is then analyzed and the effectiveness is verified. Then, a quasi-synchronization spoofer localization method (QSSL) is proposed, and it is verified that its localization performance can attain the Cramer-Rao lower bound. Above all, a field experiment demonstrates the effectiveness of the proposed methods and the feasibility of such system.

Article Citation: Wen, J., Li, H., & Lu, M. (2022). A flexible GNSS spoofer localization system: Spoofing discrimination and localization method. *NAVIGATION*, *69*(1). https://doi.org/10.33012/navi.511

WEBINARS

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

April 27, 2022 Webinar: Results on GNSS Spoofing Mitigation Using Multiple Receivers
By Dr. Gustaf Hendeby
(https://www.ion.org/publications/webinar-hendeby.cfm)

Abstract: GNSS receivers are vulnerable to spoofing attacks in which false satellite signals deceive receivers to compute false position and/or time estimates. This work derives and evaluates algorithms that perform spoofing mitigation by utilizing double differences of pseudorange or carrier-phase measurements from multiple receivers. The algorithms identify pseudorange and carrier-phase measurements originating from spoofing signals, and omit these from the position and time computation. The algorithms are evaluated with simulated and live-sky meaconing attacks. The simulated spoofing attacks show that mitigation using pseudoranges is possible in these tests when the receivers are separated by five meters or more. At 20 meters, the pseudorange algorithm correctly authenticates six out of seven pseudoranges within 30 seconds in the same simulator tests. Using carrier phase allows mitigation with shorter distances between receivers, but requires better time synchronization between the receivers. Evaluations with live-sky meaconing attacks show the validity of the proposed mitigation algorithms.

Article Citation: Stenberg, N., Axell, E., Rantakokko, J., & Hendeby, G. (2022) Results on GNSS spoofing mitigation using multiple receivers. *NAVIGATION*, *69*(1). https://doi.org/10.33012/navi.510

March 30, 2022 Webinar: Urban Positioning: 3D Mapping-aided GNSS Using Dual-frequency Pseudorange Measurements from Smartphones
By Hoi-Fung Ng and Dr. Li-Ta Hsu
(https://www.ion.org/publications/webinar-ng.cfm)

Abstract: A smartphone with a highly sensitive antenna receiving numerous unhealthy measurements suffers from non-line-of-sight (NLOS) reception and multipath effects. 3D-mapping-aided (3DMA) GNSS has been proven to be effective in urban environments. However, the multipath effect remains challenging for urban positioning. In nature, the new GNSS civilian L5-band signal with a shorter chip length shows a much better resistibility to multipath than the conventional L1-band signal. Therefore, this study integrated the multi-constellation L5-band measurements into 3DMA GNSS to improve the positioning performance in urban canyons, namely the L1-L5 3DMA GNSS. Furthermore, this study compares different approaches on the receiver clock biases estimation for 3DMA GNSS. Finally, the integration of different 3DMA GNSSs is presented. The experiments conducted using smartphone data show that the L1-L5 3DMA GNSS is available for a better position solution than the 3DMA GNSS with L1-band only, thereby achieving a positioning accuracy within 10 m on average.

Article Citation: Ng, H. -F., Zhang, G., Luo, Y., & Hsu, L.-T. (2021). Urban positioning: 3D mapping-aided GNSS using dual-frequency pseudorange measurements from smartphones. *NAVIGATION, 68*(4), 727–749. https://doi.org/10.1002/navi.448

February 22, 2022 Webinar: Using GPS Data to Understand the Relationship Between Mobility Behavior and Well-Being
By Dr. Gabriella M. Harari
(https://www.ion.org/publications/webinar-mobility.cfm)

Background: Presented by Stanford University Assistant Professor, Gabriella M. Harari, PhD, this webinar explores the fascinating findings from research examining the relationship between mobility behaviors and well-being by looking at individual differences in movement patterns assessed via GPS data (distance traveled, entropy, and irregularity) and their relationship to six indicators of subjective well-being (depression, loneliness, anxiety, stress, affect, and energy) at the between and within person level. Using data from a large smartphone-based longitudinal study (N = 778 young adults), the research shows how: a) movement tendencies over a two-week period relate to subjective depression and loneliness; and b) daily movement behaviors relate to daily affect, stress, anxiety, and energy level.

How to cite this article: Langley, R. B. (2022) Navigator Notes: Editorial Highlights from the Editor-in-Chief. *NAVIGATION, 69*(2). https://doi.org/10.33012/navi.525