Hindawi
Journal of Sensors
Volume 2024, Article ID 9757198, 1 page
https://doi.org/10.1155/2024/9757198

Retraction

Retracted: Motion Control and Tracking Control of UAV Based on Adaptive Sensor

Journal of Sensors

Received 23 January 2024; Accepted 23 January 2024; Published 24 January 2024

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] X. Zhao, Z. Xu, Y. Fu, S. Xu, and S. Xiong, "Motion Control and Tracking Control of UAV Based on Adaptive Sensor," *Journal of Sensors*, vol. 2023, Article ID 7936019, 7 pages, 2023.

Hindawi
Journal of Sensors
Volume 2023, Article ID 7936019, 7 pages
https://doi.org/10.1155/2023/7936019

Research Article

Motion Control and Tracking Control of UAV Based on Adaptive Sensor

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Received 10 July 2022; Revised 26 August 2022; Accepted 31 August 2022; Published 25 April 2023

Academic Editor: Haibin Lv

In order to meet the requirements of UAV motion control and tracking control, an adaptive sensor-based technology is proposed. The main content of the technology is based on the mathematical model of the adaptive sensor, through the quaternion attitude update model, using nonlinear attitude SVDCK filtering and dynamic adaptive adjustment factors and other technologies, and finally through simulation experiments and analysis to build the research means of UAV motion control and tracking control system. The experimental results show that the roll Angle, pitch Angle, and yaw Angle of SVDCKF are 1.703, 1.972, and 1.928, respectively. By adjusting the dynamic adaptive factor, the attitude-filtering algorithm reduces the error of the attitude solution and improves the robustness of the attitude solution under high dynamic conditions. *Conclusion*. The technology research based on adaptive sensor can meet the requirements of UAV motion control and tracking control.

1. Introduction

In many application scenarios of UAV, target tracking is a very typical task. In the process of target tracking, UAV uses its mounted sensor to continuously observe the tracked target, which can obtain a lot of information about the target, and then realize the target identification and precise positioning. Therefore, UAV target tracking has great application value in battlefield reconnaissance, ground attack, city antiterrorism, and maritime search and rescue, and has received more and more attention [1]. Four-rotor UAVs are widely used in surveying, mapping, monitoring, and other fields due to their small appearance and easy concealment. In some specific scenarios, it is necessary to pay attention to the flight status of the UAV at all times, so the visual tracking of the UAV is particularly important, and the challenge of realizing efficient visual tracking lies in the reasonable appearance of the target and the selection of appropriate tracking strategy.

Due to the influence of UAV motion constrained sensor observation range and complex environmental conditions, a single UAV is usually not enough to achieve accurate and continuous target tracking. Therefore, multiple UAVs are needed to maintain the robustness of target tracking task and obtain higher target positioning accuracy. Compared with single UAV target tracking, multi-UAV cooperative target tracking has two key problems. Collaborative fusion estimation of target state, that is, how to effectively fuse the target observations from different UAVs to obtain the optimal estimation of target state. Trajectory optimization decision of cooperative target tracking and observation by multiple UAVs, namely, how to coordinate the movement of these UAVs to obtain better observation of the target (to optimize the performance of target state estimation) [2]. Therefore, at present, domestic and foreign scholars have carried out a lot of research on these two key problems in cooperative target tracking of multiple UAVs. With the rapid development of UAV technology, it has gradually been applied to aerial photography, aerial detection, geographic mapping, power line inspection, personnel search, express delivery, maritime rescue, agricultural plant protection, environmental monitoring, and other fields. With the rapid development of UAV technology, autonomous tracking and landing of dynamic targets by UAV has become a key issue for many researchers.

With the rapid development of modern science and technology, UAV technology is widely used in surveying, geology, meteorology, plant protection, inspection and monitoring, and other fields, and the application of UAV + industry is in the ascendant [3]. With the rapid development of UAV information technology, lightweight and miniaturized mission load technology, satellite communication technology, composite material structure technology, high efficiency aerodynamics technology, new energy and high efficiency power technology, integration technology of light and small sensors and data processing system, and take-off and landing technology, the performance of UAV is constantly improving. Functions continue to expand, various types of UAVs continue to emerge, and the application field is more and more extensive.

2. Literature Review

At present, UAV attitude calculation algorithms mainly include complementary filtering, Kalman filtering, and so on. Among them, complementary filtering relies on the frequency complementary characteristics between sensors and fuses sensor data to calculate the heading. UAV technology is widely used in today's society. UAV has the characteristics of low-cost, high efficiency, maneuver, flexibility, real-time, high resolution, simple operation, high image resolution, and little influence by terrain factors. It can adapt to a complex environment outside, and has good controllability of flight routes during aerial survey, which can be set according to actual needs. As an aerial IoT device, UAV has many different characteristics from low-orbit satellites and ground networks. UAV has lower path loss and is very beneficial to wireless transmission in the Internet of Things because of its on-demand deployment in hover mode [4]. However, the excessive dependence of the cellular Internet of Things on ground infrastructure is not conducive to the deployment of the Internet of Things in remote areas and disaster areas. In contrast, UAVs have the flexibility to respond quickly to remote operations and control, can deploy IoT quickly without ground infrastructure, and UAVs have air superiority and access to better line-of-sight links, conducive to sending information sufficiently close to IoT devices. As a result, UAVs can quickly meet a variety of business needs, such as providing data offloading wireless coverage communications relays and edge computing for hot spot disasters and remote areas as well as military operations. UAV aerial photography is a combination of visible light camera, infrared thermal imager, hyperspectral imager, laser radar and image transmission equipment carried by UAV, and aircraft with image transmission technology to transmit high-definition pictures in real-time and complete image information processing of the control area. Unmanned aerial vehicle (UAV) with the aid of wireless control technology and process control devices to operate applications, use of prior planning process to realize the automatic operation intelligent vehicle has the most advanced visual system and sensor system, can be in a stable hover flight, with automatic returning obstacles perception and auxiliary function, and can carry specified parts to adapt to different scenarios [5].

To solve the above problems, in order to meet the requirements of UAV motion control and tracking control, an adaptive sensor-based technology is proposed. The main content of the technology is based on the mathematical model of the adaptive sensor, through the quaternion attitude update model, using nonlinear attitude SVDCK filtering and dynamic adaptive adjustment factors and other technologies, and finally through simulation experiments and analysis to build the research means of UAV motion control and tracking control system. For small unmanned aerial vehicle (UAV) under the condition of complex flight navigation position of calculating precision and robustness problem, this paper proposes a dynamic adaptive adjustment of the singular value volume navigation pose estimation of the Kalman filter algorithm, considering the low-cost airlines posture sensor random, the problem of large deviation, the navigation position sensor random deviation as to estimate parameters and to eliminate the influence of stochastic error sensor [6].

3. Research Method

3.1. Adaptive Sensor Mathematical Model

3.1.1. Quaternion Attitude Update Model. In the attitude representation method of UAV strapdown, unit quaternion is usually used for fast calculation of attitude update and rigid body transformation, as shown in the following:

$$q = q_w + q_x i + q_y j + q_z k = \begin{bmatrix} q_w \\ q_v \end{bmatrix} = \begin{bmatrix} \cos(\theta/2) \\ e_x \sin(\theta/2) \\ e_y \sin(\theta/2) \\ e_z \sin(\theta/2) \end{bmatrix}. \quad (1)$$

In the formula, q_w is the real part of a quaternion, q_v is the imaginary part of a quaternion, and e is the rotation axis. Quaternion continuous multiplication operation can be defined by the following:

$$p \otimes q = \begin{bmatrix} p_w q_w - p_v^{\mathrm{T}} q_v \\ p_w q_v + q_w p_v + p_v \times q_v \end{bmatrix}, \quad (2)$$

$$q \otimes q^{-1} = [1, 0, 0, 0]^{\mathrm{T}}. \quad (3)$$

In formulas (2) and (3), the quaternion multiplication operator is a reversible quaternion of q, and the quaternion must satisfy the orthogonal principle of

$$|q| = \sqrt{q \otimes q^{-1}} = \sqrt{q_w^2 + q_x^2 + q_y^2 + q_z^2} = 1. \quad (4)$$

In this paper, the unit quaternion is used to update the UAV attitude, the quaternion attitude differential equation is solved by the first-order Picard's substitution method, and the discrete model is given [7, 8].

Attitude calculation is dependent on measurements from attitude sensors using low-cost attitude sensors, mainly including gyroscopes, accelerometers, and magnetometers. These sensors are attached to the center of gravity of the small UAV body, and the three axes of the sensor are orthogonal to each other under ideal conditions [9].

UAV attitude model is a nonlinear system in practice. Therefore, this paper establishes the nonlinear system model of UAV attitude in the Gaussian discrete state, as shown in the following:

$$\begin{cases} x_k = f(x_{k-1}, v_{k-1}) + m_{k-1}, \\ z_k = h(x_k) + n_k. \end{cases} \tag{5}$$

In the formula x_k is the attitude state estimation parameters, $f(\cdot)$ is the nonlinear dynamic function, v_{k-1} is the attitude sensor input parameters, z_k is the attitude observation parameters, and $h(\cdot)$ is the nonlinear observation function. Among them, m_{k-1} and n_k are system dynamic noise and observation noise, respectively. It is assumed that both of them are zero-mean Gaussian white noise and unrelated.

3.1.2. Nonlinear Attitude SVDCK Filtering. For nonlinear pose filtering, CKF filtering method is adopted in this paper, which has better solution accuracy than EKF and UKF. The Cholesky decomposition state covariance matrix P and $P = U^{`}U, U$ is the triangular matrix [10]. However, there are some problems with using the Cholesky decomposition.

1. When Cholesky decompose the state covariance matrix P, P must satisfy the property of positive definite or symmetric positive definite, which limits the value range of P and leads to unstable attitude solution
2. The state covariance matrix may become a sparse matrix during the operation of the attitude-filtering algorithm, which destroys the requirement of Cholesky's decomposition for P

Therefore, this paper uses Singular Value Decomposition (SVD) to replace Cholesky's decomposition, so that the state covariance matrix P can overcome the above problems as shown in Figure 1.

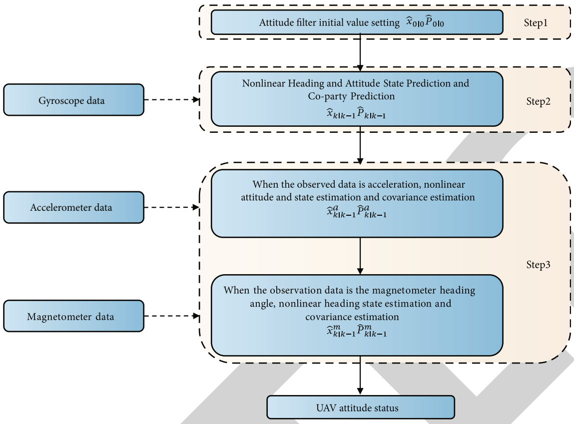

Figure 1: Block diagram of nonlinear attitude filtering.

3.1.3. Dynamic Adaptive Regulatory Factor. Under different flight conditions of UAV, the triaxial acceleration of the accelerometer will change greatly, especially some harmful acceleration or abnormal measurement values may affect the value of acceleration [11]. Also, during the drone flight, body jitter and turbulence will also make the acceleration value uncertain. Therefore, based on the adaptive adjustment of the noise variance of the sensor, a dynamic adaptive adjustment factor is designed to improve the noise variance of the accelerometer. And, the flight conditions of UAV are divided into static conditions, low dynamic conditions, and high dynamic conditions. Figure 2 is the block diagram of dynamic adaptive SVDCKF filter, in which the dynamic acceleration factor can be defined by the following:

$$\partial = \left| \sqrt{a_{fx}^2 + a_{fy}^2 + a_{fz}^2} - g \right|. \tag{6}$$

1. Static condition: before the UAV takes off, the flight state on the horizontal ground can be assumed to be in static condition. At this time, the triaxial acceleration is only affected by the local gravitational acceleration and slight shake of the body. Due to the use of low-cost inertial devices, the device itself has great sensor noise [12]
2. Under low dynamic conditions: the UAV is affected by body jitter and airflow disturbance in the flight process, which is transmitted to the accelerometer and produces harmful accelerations. These harmful accelerations will pollute the triaxial acceleration value and then lead to the failure of UAV attitude calculation [13]
3. In high dynamic conditions, the UAV can be disturbed by some bad factors during flight, such as strong winds, turbulence, and birds. These sudden and dramatic changes will all cause triaxial acceleration to be unusable

3.1.4. Key Technology. The key technology of UAV full-flight self-optimizing control in complex environment integrates advanced information technology, communication technology, control technology, sensor technology, and system integration technology. The intelligent control of traditional PID flight control system is optimized by using the modern control technology of artificial intelligence and the analysis and fusion of a large number of flight case data [14].

Complex environment refers to complex geographical environment, complex meteorological environment, complex electromagnetic environment, complex scenes, and a variety of complex UAV platform models.

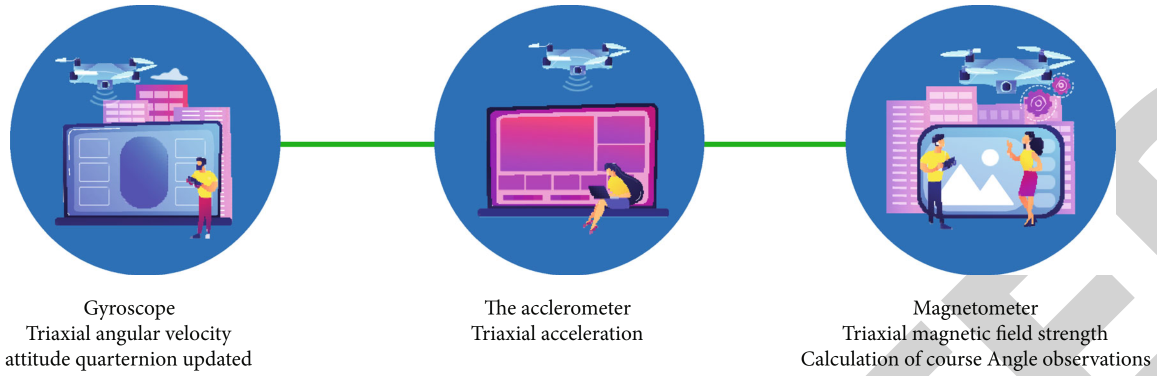

FIGURE 2: Adaptive filtering block diagram of SVDCKF.

(1) The nonlinear adaptive variable parameter control algorithm, fault self-diagnosis, and control law reconstruction are proposed to solve the problem of accurate control of UAV trajectory and navigation point in complex environment. The whole process control strategy control process and control algorithm of UAV from takeoff to landing are proposed to realize intelligent and accurate autonomous control of UAV in complex environment [15]

(2) Based on the pilot following method, artificial potential field method, virtual structure method, and behavior-based method, the optimal estimation filter and vertical high-order control loop were constructed by integrating multisensor information under different mission requirements and aircraft type conditions. The problem of precise cooperative control and collision avoidance of multiple aircraft formations is solved, and the cooperative formation flight of UAVs in wide airspace with long distance and large speed is realized [16]

3.2. Simulation Experiment

3.2.1. Experimental Platform and Analysis. In this paper, the experimental platform is used to collect UAV attitude sensor data, including MPU6500 inertial measurement unit and HMC5893 magnetometer. During the experiment, rotor UAV was used to collect attitude sensor data under static and low dynamic conditions, and fixed wing UAV was used to collect attitude sensor data under high dynamic conditions [17].

In order to better verify the performance of the proposed attitude-filtering algorithm, the collected attitude sensor data is used to analyze the algorithm on the simulation software, and the algorithm is compared with EKF and CKF attitude filtering [18].

Figure 3 describes the variation of UAV's triaxial acceleration under static conditions. Compared with EKF and CKF, the attitude error of the proposed aeropose-filtering algorithm is the smallest. Since the variation of triaxial acceleration under static conditions is relatively stable, the measurement noise has little influence on the accuracy of aeropose. In this case, the accurate nonlinear attitude model and the high-dimensional nonlinear attitude-filtering algorithm will affect the solution of the attitude accuracy [19]. In this paper, a 13-dimensional attitude estimation model and high-dimensional singular value volumetric Kalman filter are designed to improve the accuracy of attitude filtering and reduce the interference of some uncertain factors.

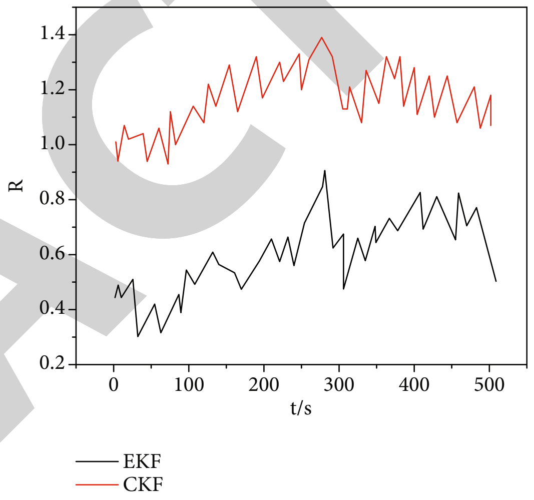

FIGURE 3: Roll Angle, pitch Angle, and yaw Angle error diagram under static condition.

Figure 4 describes the variation of UAV's triaxial acceleration under low dynamic conditions. Under low dynamic conditions, EKF's attitude filtering attitude error is the largest, mainly because EKF introduces rounding error to the first-order truncation description of nonlinear attitude model, which is then transmitted to the attitude solution and amplifies the error of attitude solution [20]. Although the attitude calculation error of CKF is smaller than that of EKF, the measured value of triaxial acceleration will be interfered by some uncertain factors during low dynamic flight. At this time, the acceleration noise will be constantly changing. CKF cannot eliminate the influence brought by these disturbances because the constant acceleration noise variance is set. Therefore, a dynamic adaptive adjustment factor is designed in this paper, through which the acceleration noise variance is constantly adjusted to reduce the attitude error.

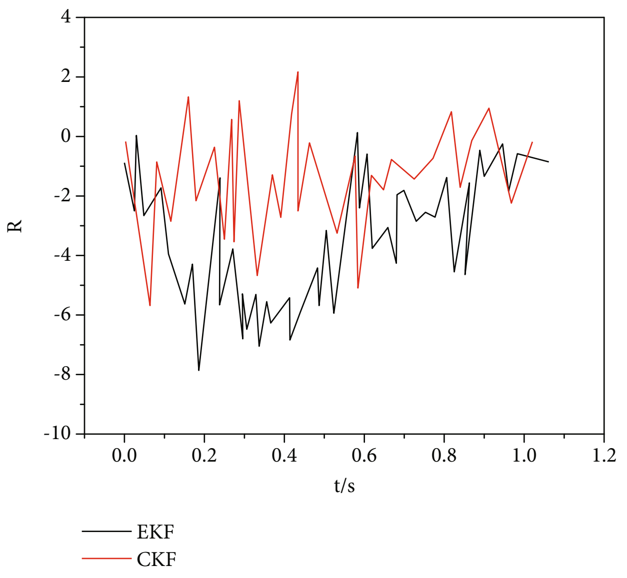

Figure 4: Error diagram of roll Angle, pitch Angle, and yaw Angle under low dynamic condition.

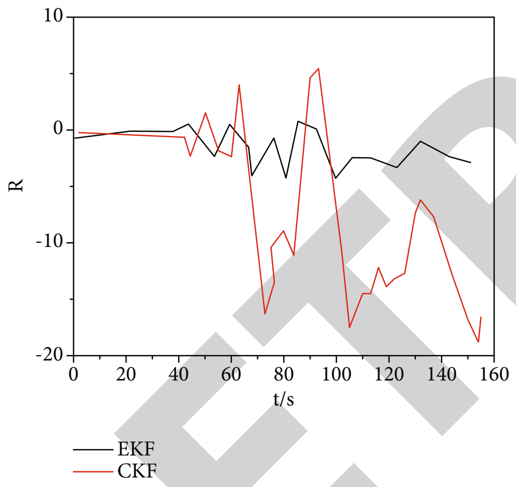

Figure 5: Roll Angle, pitch Angle, and yaw Angle error diagram under high dynamic condition.

Figure 5 describes the variation of UAV's triaxial acceleration under high dynamic conditions. In low dynamic conditions, fixed-wing UAV is used in this paper to collect attitude sensor data under high dynamic flight conditions. Compared with rotor-wing UAV, fixed-wing UAV has faster flight speed and more flexible maneuvering. The attitude error of EKF attitude filter changes sharply after 40s. This is because, under high dynamic conditions, the nonlinear degree of the sailing attitude model is enhanced, which leads to an increasingly large rounding error caused by EKF first-order truncation. Under high dynamic conditions, SVDCKF with dynamic adaptive adjustment factor has better processing effect on the acceleration measurement noise than CKF, which eliminates the influence of nonacceleration on the attitude calculation and improves the calculation accuracy.

Table 1: Comparison of attitude accuracy among EKF, CKF, and SVDCKF.

Method		The attitude angle/(°)		
		Roll angle *R*	Angle of pitch *P*	Yaw angle *Y*
EKF	MAE	3.294/7	5.147/8	6.011/5
	STD	6.007/5	9.869/7	12.594/0
	RMSE	9.037/3	14.801/0	22.694/0
CKF	MAE	2.712/3	3.714/3	4.014/3
	STD	5.057/0	6.510/5	6.380/4
	RMSE	6.786/8	7.608/6	10.264/0
SVDCKF	MAE	1.703/6	1.972/3	1.928/0
	STD	3.548/2	4.396/8	4.467/2
	RMSE	3.335/1	3.436/3	4.136/2

4. Interpretation of Result

In this paper, a SVDCKF nonlinear attitude-filtering algorithm with dynamic adaptive adjustment factor is proposed. Taking small unmanned aerial vehicle (UAV) as the research object, the attitude calculation requirements of UAV during flight are analyzed and designed, which improves the accuracy and robustness of UAV attitude calculation. Compared with other attitude algorithms, the proposed attitude algorithm has the following advantages:

(1) A nonlinear attitude system model of the attitude state was designed, and the random errors of the gyroscope accelerometer and magnetometer were used as state estimation parameters to eliminate the influence of the random errors of the attitude sensor on the accuracy of the attitude solution

(2) In view of the nonlinear problem of UAV attitude model and matrix nonpositive definite problem of state covariance in the filtering process, singular value decomposition was used to replace Cholesky's decomposition, and then combined with volume Kalman filter, the nonlinear attitude model was processed to improve the accuracy of attitude solution [21].

(3) A dynamic adaptive adjustment factor was designed to deal with the variance of acceleration measurement noise, which improved the robustness and immunity of the attitude filtering

Table 1 provides the mean absolute error standard deviation and root mean square error of EKF, CKF, and SVDCKF attitude accuracy of UAV under high dynamic conditions. As can be seen from Table 1, the value of SVDCKF roll Angle is 1.703, pitch Angle is 1.972, and yaw Angle is 1.928. By adjusting the dynamic adaptive factor, the proposed algorithm can reduce the error of attitude calculation and improve the robustness of attitude calculation under high dynamic conditions.

5. Conclusion

To solve the above problems, in order to meet the requirements of UAV motion control and tracking control, an adaptive sensor-based technology is proposed. The main content of the technology is based on the mathematical model of the adaptive sensor, through the quaternion attitude update model, using nonlinear attitude SVDCK filtering and dynamic adaptive adjustment factors and other technologies, and finally through simulation experiments and analysis to build the research means of UAV motion control and tracking control system. Considering the influence of the triaxial acceleration in the attitude sensor on UAV attitude calculation under different flight conditions, a dynamic adaptive factor was proposed based on the idea of adaptive filtering to continuously adjust the noise variance of the acceleration measurement, which improved the robustness of the attitude filtering under complex conditions. Aiming at the nonlinear problem of the UAV's attitude model and the matrix nonpositive definite problem of the state covariance in the filtering process, the singular value decomposition is used to replace the Cholesky decomposition, and then combined with the volumetric Kalman filter, the nonlinear attitude model is analyzed. Processing to improve the accuracy of the attitude calculation, experimental results show that the proposed algorithm not only effectively improves the accuracy of the nonlinear attitude model and meets the flight requirements of small UAVs but also eliminates the influence of the random deviation of the attitude sensor and the noise of the triaxial acceleration measurement on the attitude solution, and improves the robustness and immunity of the algorithm.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] L. Hou, F. Lian, S. Tan, C. Xu, and G. Abreu, "Robust generalized labeled multi-bernoulli filter for multitarget tracking with unknown non- stationary heavy-tailed measurement noise," *IEEE Access*, vol. 9, pp. 94438–94453, 2021.

[2] M. Beauchamp, R. Fablet, C. Ubelmann, M. Ballarotta, and B. Chapron, "Intercomparison of data-driven and learning-based interpolations of along-track nadir and wide-swath swot altimetry observations," *Remote Sensing*, vol. 12, no. 22, p. 3806, 2020.

[3] P. B. Holden, A. J. Rebelo, and M. G. New, "Mapping invasive alien trees in water towers: a combined approach using satellite data fusion, drone technology and expert engagement," *Remote Sensing Applications Society and Environment*, vol. 21, no. 1, article 100448, 2021.

[4] B. Rohman, M. B. Andra, and M. Nishimoto, "Through-the-wall human respiration detection using uwb impulse radar on hovering drone," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 14, pp. 6572–6584, 2021.

[5] I. F. Ammarprawira, M. S. Fauzi, A. Jabbaar, and N. Syafitri, "Implementasi automatic waypoint untuk return trip pada autonomous robot dengan titik acuan potensi korban bencana," *ELKOMIKA Jurnal Teknik Energi Elektrik Teknik Telekomunikasi & Teknik Elektronika*, vol. 8, no. 1, p. 203, 2020.

[6] L. Su and V. Lau, "Data and channel-adaptive sensor scheduling for federated edge learning via over-the-air gradient aggregation," *IEEE Internet of Things Journal*, vol. 9, no. 3, pp. 1640–1654, 2022.

[7] Z. Wang, K. M. Schmalbach, R. L. Penn, D. Poerschke, and A. Stein, "3d periodic and interpenetrating tungsten-silicon oxycarbide nanocomposites designed for mechanical robustness," *ACS Applied Materials & Interfaces*, vol. 13, no. 27, pp. 32126–32135, 2021.

[8] M. Roelfs, D. Dudal, and D. Huybrechs, "Quaternionic step derivative: machine precision differentiation of holomorphic functions using complex quaternions," *Journal of Computational and Applied Mathematics*, vol. 398, no. 3, article 113699, 2021.

[9] R.-. F. Li, X.-X. Wang, L. Wu et al., "Xanthomonas campestris sensor kinase hpas co-opts the orphan response regulator vemr to form a branched two-component system that regulates motility," *Molecular Plant Pathology*, vol. 21, no. 3, pp. 360–375, 2020.

[10] S. Chen, Y. Shen, Y. Yan, D. Wang, and S. Zhu, "Cholesky decomposition-based metric learning for video-based human action recognition," *Access*, vol. 8, pp. 36313–36321, 2020.

[11] S. Yang, X. Hu, X. Wang, and D. Li, "A structure scheme to reduce the influence of the accelerometer inner lever-arm effect on tri-axis inertial navigation systems," *Measurement Science and Technology*, vol. 32, no. 5, article 055103, 2021.

[12] C. Dang, J. Li, and J. Tang, "Systematic research on measuring acceleration of gravity by laser interferometry," *Journal of Physics: Conference Series*, vol. 1982, no. 1, article 012146, 2021.

[13] M. Albacha, L. Rambault, A. Sakout, K. A. Meraim, and S. Cauet, "Software sensor for airflow modulation and noise detection by cyclostationary tools," *Sensors*, vol. 20, no. 8, p. 2414, 2020.

[14] C. N. Umstead, K. M. Unertl, N. M. Lorenzi, and N. L. Lovett, "Enabling adoption and use of new health information technology during implementation: roles and strategies for internal and external support personnel," *Medical Informatics*, vol. 28, no. 7, pp. 1543–1547, 2021.

[15] A. Bakushinsky and A. Smirnova, "A study of frozen iteratively regularized gauss–newton algorithm for nonlinear ill-posed problems under generalized normal solvability condition," *Journal of Inverse and Ill-Posed Problems*, vol. 28, no. 2, pp. 275–286, 2020.

[16] X. Yan, D. Jiang, R. Miao, and Y. Li, "Formation control and obstacle avoidance algorithm of a multi-usv system based on virtual structure and artificial potential field," *Journal of Marine Science and Engineering*, vol. 9, no. 2, p. 161, 2021.

[17] A. Sharma and R. Kumar, "Performance comparison and detailed study of AODV, DSDV, DSR, TORA and OLSR routing protocols in ad hoc networks," in *2016 Fourth International Conference on Parallel, Distributed and Grid Computing*, pp. 732–736, Waknaghat, India, 2016.

[18] J. Jayakumar, S. Chacko, and P. Ajay, "Conceptual implementation of artificial intelligent based E-mobility controller in smart city environment," *Wireless Communications and Mobile Computing*, vol. 2021, Article ID 5325116, 8 pages, 2021.

[19] J. Chen, J. Liu, X. Liu, W. Gao, J. Zhang, and F. Zhong, "Degradation of toluene in surface dielectric barrier discharge (SDBD) reactor with mesh electrode: synergistic effect of UV and TiO_2 deposited on electrode," *Chemosphere*, vol. 288, no. 3, article 132664, 2022.

[20] R. Huang, "Framework for a smart adult education environment," *World Transactions on Engineering and Technology Education*, vol. 13, no. 4, pp. 637–641, 2015.

[21] H. Xie, Y. Wang, Z. Gao, B. Ganthia, and C. Truong, "Research on frequency parameter detection of frequency shifted track circuit based on nonlinear algorithm," *Nonlinear Engineering*, vol. 10, no. 1, pp. 592–599, 2021.