International Core Journal of Engineering | Volume 7 Issue 3, 2021
ISSN: 2414-1895 | DOI: 10.6919/ICJE.202103_7(3).0055

Research on Target Tracking Technology of Multi-rotor Aircraft Based on ICDKF

Qianqian Wang

School of Information Engineer, Shanghai Maritime University, Shanghai 000000, China.

1154060136@qq.com

Abstract

Multi-rotor aircraft has a wide range of applications and great potential in shooting, inspection, tracking and other fields because of its advantages such as flexible mobility, simple design and increasingly lower production cost. In this paper, the target tracking technology of multi-rotor aircraft is studied. For the control of aircraft, because of its obvious non-linearity, it is necessary to design an efficient and stable control system. The target tracking of multi-rotor aircraft is mainly faced with the measurement deviation of sensors in complex situations. These factors will seriously affect the accuracy of target tracking, or even lose the target. The unknown system deviation exists in the measurement information of the airborne radar when the multi-rotor aircraft is tracking the target.In this paper, an incremental center Kalman filter algorithm is proposed. The simulation results show that the algorithm can effectively reduce the adverse effects of measurement deviation in maneuvering target tracking, improve the target tracking accuracy, and achieve good results.

Keywords

Aircraft; Target Tracking; ICDKF; Sensor.

1. Introduction

All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Multi-rotor aircraft is a reusable unmanned aerial vehicle that generally has more than or equal to four rotors to provide flight lift, and the rotors are symmetrically distributed around the body, positive and negative turn into pairs, and realize autonomous flight to complete the indicated goal [1]. Different from fixed-wing aircraft, multi-rotor aircraft has the advantages of simple structure, can realize vertical take-off and landing, fixed hover and so on.Since multi-rotor aircraft has the advantage of vertical take-off and landing, it does not need a fixed place when taking off, so it has a wide application prospect and huge potential in many fields such as patrol and photography [2]. However, due to the complex nonlinear and multivariable strong coupling characteristics of multi-rotor aircraft system, there are still many challenges to realize its autonomous control. Therefore, various technical researches on multi-rotor aircraft have become the current key research objectives [3].

In order to accurately obtain from biased measurement value of target position, speed and other key information, the development of target tracking filter technology from classic particle filter and kalman filter tracking method, to the method, based on the test or related filtering to the depth of the latest methods of learning, the method based on tracking filter is more and more abundant.Particle filtering is a model estimation technique based on stochastic simulation.In the target tracking technology, the tracking target model is used to select a probability density to meet the approximate degree of particle and target, so as to get the approximate optimal solution of the target model. Kalman

ISSN: 2414-1895 DOI: 10.6919/ICJE.202103_7(3).0055

filtering is based on the motion model of the target and is used to estimate the state of the target at the next moment without modeling the characteristics of the target [4]. The classical Kalman filter is optimal when the process and measurement noise of the system can be modeled as Gaussian white noise. Any colored noise or deviation in the system may reduce the filtering performance, especially the sensor measurement deviation in the target tracking system. In order to improve the tracking performance, it is necessary to reduce or compensate the measurement deviation of the sensor in the target tracking system.

Many ideas have been proposed to mitigate the negative effects of measurement bias. One idea is to expand the dimension of the deviation into the state vector for estimation; however, for ill - condition systems, this expansion strategy may not be computable. Friedland proposed a parallel reduced-order filtering separation bias estimation, and proved that it was equivalent to the above dimension expansion strategy [5]. Schmidt proposed a Kalman filter to solve the bias of the system, which takes into account the cross-covariance between the bias and the state, but does not estimate them.

In target tracking system, the estimation of the unknown measurement deviation is an important factor. Unknown deviation error will cause model mismatch [6].

The aircraft target tracking algorithm based on incremental center Kalman filter is designed to solve the problem of unknown system deviation when multi-rotor aircraft track the target. Based on the principle of independent increment, the incremental measurement equation is established, and the general ICDKF algorithm and the additive ICDKF algorithm are proposed.In view of three different types of measurement deviation, the ICDKF algorithm proposed in this paper and the traditional CDKF algorithm were verified and analyzed by Matlab simulation.

2. Modeling and analysis of multi-rotor aircraft

In most cases, multi-rotor aircraft fly at a low altitude and at a low speed [7]. In order to establish a mathematical model that is easy to calculate, the following assumptions are put forward in this paper:

The multi-rotor aircraft is regarded as a rigid body with symmetrical mechanical structure and uniform mass. The body coordinate system and the body mass center of gravity coincide; The influence of vibration and deformation of the propeller of multi-rotor aircraft is ignored.

According to the above assumptions, the motion of multi-rotor aircraft can be seen as rigid body motion, and its motion equation includes two parts: kinematics equation and dynamics equation. The former does not involve the influence of force and mass and studies the movement of the body from the perspective of geometry, while the latter studies the relationship between the movement of the body and the forces and torques acting on the body.

The force generated on the multi-rotor aircraft is mainly generated by the rotation of four rotors. In the body coordinate system, there are:

$$F_B = \begin{bmatrix} 0 \\ 0 \\ \sum_{i=1}^{4} F_i \end{bmatrix} \tag{1}$$

The acceleration equation of the aircraft is:

$$\begin{cases} m\ddot{x} = \sin\theta\cos\phi\cos\psi + \sin\phi\sin\psi\sum_{i=1}^{4} F_i \\ m\ddot{y} = \sin\theta\cos\phi\cos\psi - \sin\phi\sin\psi\sum_{i=1}^{4} F_i \\ m\ddot{z} = \cos\phi\cos\theta\sum_{i=1}^{4} F_i - mg \end{cases} \tag{2}$$

ISSN: 2414-1895
DOI: 10.6919/ICJE.202103_7(3).0055

The combined moment in the geographic coordinate system is:

$$M=\begin{bmatrix} I_x\dot{p}+rq\left(I_z-I_y\right) \\ I_y\dot{q}+pr\left(I_x-I_z\right) \\ I_z\dot{r}+pq\left(I_y-I_x\right) \end{bmatrix} \tag{3}$$

Pitching moment formula is:

$$M_\theta=L\left(F_1+F_2-F_3-F_4\right) \tag{4}$$

The yaw moment formula is:

$$M_\psi=c\left(-F_1+F_2-F_3+F_4\right) \tag{5}$$

The formula of roll moment is as follows:

$$M_\phi=L\left(F_1-F_2-F_3+F_4\right) \tag{6}$$

The moment of inertia of the aircraft in the X axis is:

$$I_x=m\left(\sqrt{2}d\right)^2/2+\left(MR^2/4+MH^2/12\right) \tag{7}$$

The moment of inertia of the aircraft about the Z axis is:

$$I_z=MR^2/2+4md^2 \tag{8}$$

3. Algorithm of aircraft target tracking

In this chapter, we use the airborne radar to track the maneuvering target. Firstly, the state model and the multi-rotor vehicle target tracking measurement model with deviation are established. Then, according to the principle of independent increment, the incremental measurement equation is designed. Secondly, based on the above incremental measurement equation, the general ICDKF algorithm and the additive ICDKF algorithm are derived.

Target tracking is a technology that measures signals through one or more sensors and uses computers to complete signal processing [8]. Maneuvering target tracking usually adopts Kalman filter algorithm to make one or more step prediction of target state, which is used to get the target position, speed, acceleration and other motion characteristics, so as to guide the target tracking system to adjust the state in time, and achieve the purpose of reducing tracking error.In order to ensure the accuracy of estimation, Kalman filter needs to establish accurate state model and measurement model.

Measurement refers to the measurement value that is related to the maneuvering target measured by the sensor. For maneuvering targets, the measured values mainly include target distance, azimuth Angle, pitch Angle, time difference, frequency difference, signal strength and so on. Due to the complexity of maneuvering target environment, sensor faults, external interference, improper selection of model parameters and other factors, the measurement information often contains errors, including deterministic systematic errors (also known as deviations) and random errors [9]. The deviation in the measurement information will lead to the reduction of the accuracy of state estimation, and even lead to the divergence of the entire filter, which will bring unexpected consequences. Therefore, the deviation in the measurement information must be compensated or calibrated effectively.

The measurement model with deviation in polar coordinates is:

$$z_k=h\left(x_k,b_k,v_k\right)=\begin{bmatrix} \left(1+s_k^r\right)r_k+o_k^r+v_k^r \\ \left(1+s_k^\varphi\right)\varphi_k+o_k^\varphi+v_k^\varphi \end{bmatrix} \tag{9}$$

Modeling is a constant variable, a mutation variable or a first-order Markov random variable, so the above equation can be rewritten as:

ISSN: 2414-1895 DOI: 10.6919/ICJE.202103_7(3).0055

$$z_k = \begin{bmatrix} r_k \\ \varphi_k \end{bmatrix} + \Gamma_k b_k + \begin{bmatrix} v_k^r \\ v_k^\varphi \end{bmatrix} \tag{10}$$

When the sampling time of the system is very short, the difference of the deviation values of the two adjacent direction finding quantities is relatively small. Since the deviation of the system itself is not very large, the deviation of the difference of the deviation is even smaller, which can be defined as the zero-mean Gaussian white noise or ignored directly.Based on the above theory, the incremental measurement model of the radar can be established as:

$$\begin{aligned} \Delta z_k &= h\left(x_k, b_k, x_{k-1}, b_{k-1}, \mathrm{v}_k^*\right) \\ &= h\left(x_k, b_k, v_k\right) - h\left(x_{k-1}, b_{k-1}, v_{k-1}\right) \\ &= \begin{bmatrix} r_k - r_{k-1} + v_k^{*r} \\ \varphi_k - \varphi_{k-1} + v_k^{*\varphi} \end{bmatrix} \end{aligned} \tag{11}$$

The sensor measurement equation with offset deviation can be expressed as:

$$\Delta z_k = \begin{bmatrix} r_k - r_{k-1} \\ \varphi_k - \varphi_{k-1} \end{bmatrix} + \begin{bmatrix} v_k^{*r} \\ v_k^{*\varphi} \end{bmatrix} \tag{12}$$

Calculate the Sigma point for the time update:

$$\chi_{k/k-1}^{\alpha} = \left(\hat{x}_{k-1}^{\alpha x}, \hat{x}_{k-1}^{\alpha w}, u_{k-1}\right) \tag{13}$$

One-step prediction for calculating the state of the system:

$$\hat{x}_{k/k-1} = \sum_{i=0}^{2n} w_i^{(m)} \chi_{i,k/k-1}^{x} \tag{14}$$

4. Target tracking simulation

If you follow the “checklist” your paper will conform to the requirements of the publisher and facilitate a problem-free publication process.

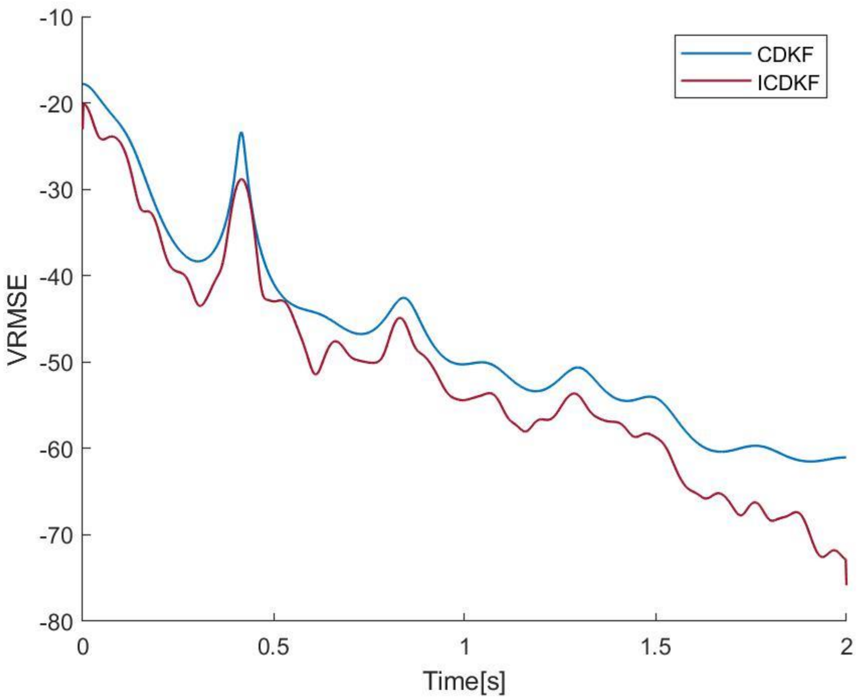

Fig. 1 Type 1 CDKF and ICDKF position estimation

ISSN: 2414-1895 DOI: 10.6919/ICJE.202103_7(3).0055

In this section, MATLAB software is used to simulate and verify the tracking effect of the proposed ICDKF algorithm in maneuvering target tracking, and it is compared and analyzed with the classical CDKF algorithm.

Type 1: Systematic error with zero mean deviation. In this case, the mean deviation is zero, that is, there is no deviation in the measurement model.

Type 2: Systematic errors are abrupt deviations. The measurement deviation increases suddenly at a certain point, lasts for a period of time, and then disappears suddenly.

Type 3: first-order Markov processes with fixed systematic errors.

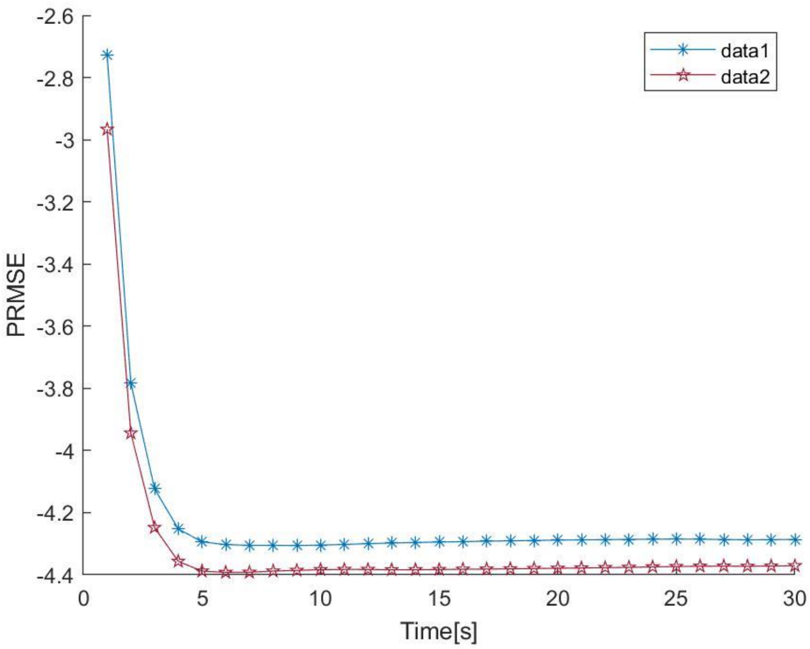

Fig. 2 Type 1 CDKF and ICDKF speed estimation

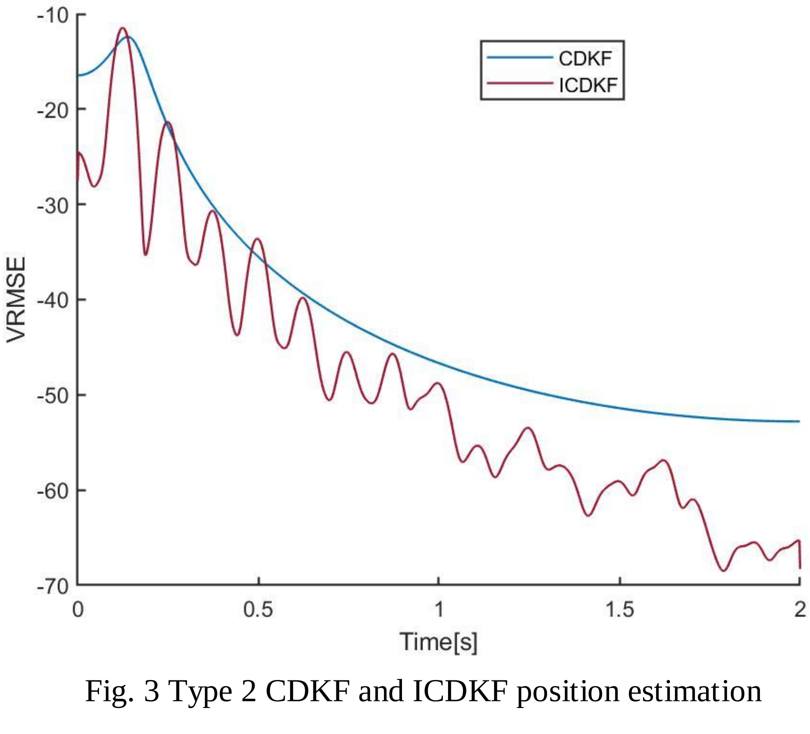

Fig. 3 Type 2 CDKF and ICDKF position estimation

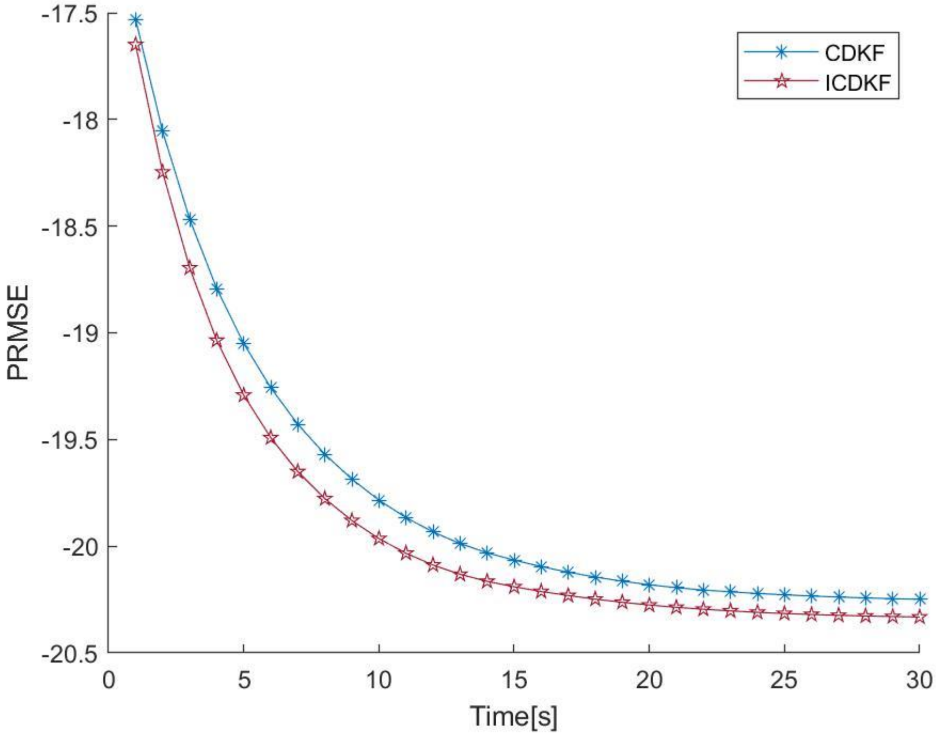

Fig. 4 Type 2 CDKF and ICDKF speed estimation

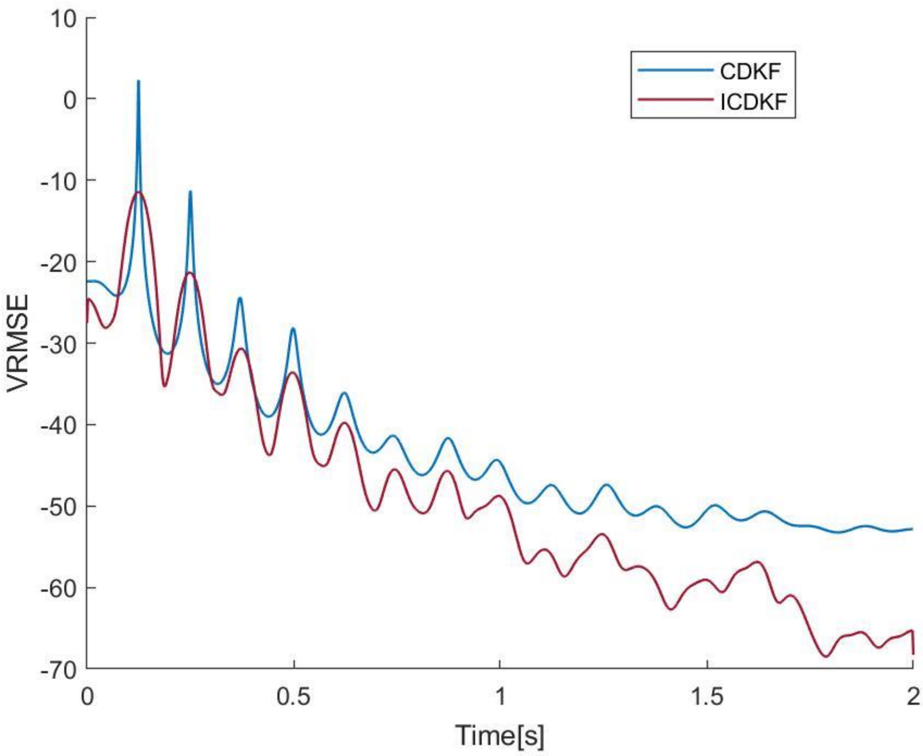

Fig. 5 Type 3 CDKF and ICDKF position estimation

The simulation results show that in most cases, the proposed ICDKF algorithm is superior to the CDKF algorithm, and the ICDKF algorithm has smaller state estimation errors for the three kinds of cases with biases: random constant deviation, abrupt deviation and time-varying deviation.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202103_7(3).0055

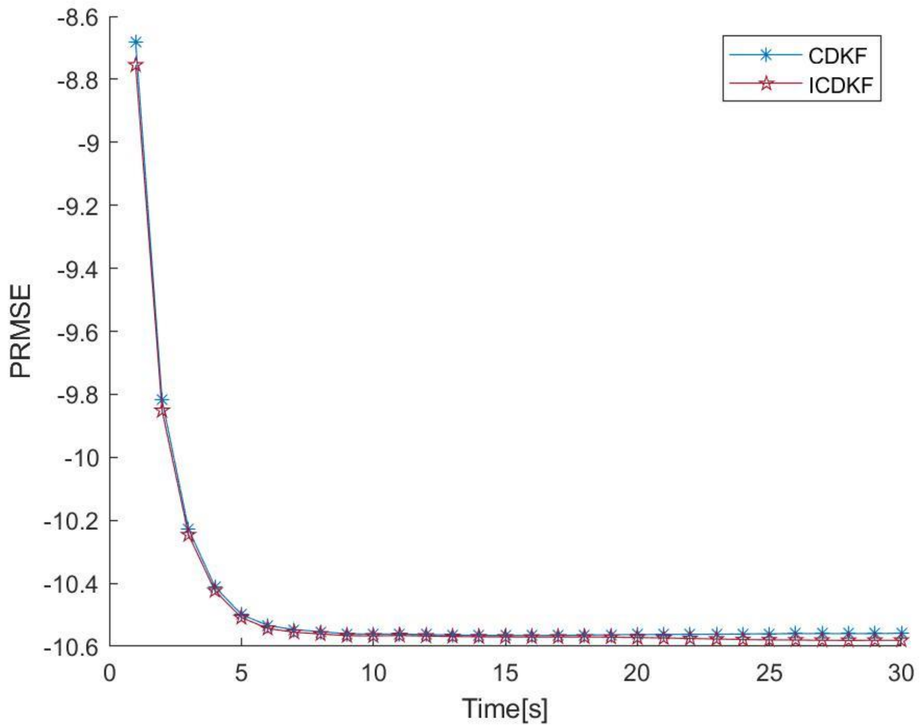

Fig. 6 Type 3 CDKF and ICDKF speed estimation

5. Conclusion

In order to solve the problem of system unknown deviation in the process of target tracking of multi-rotor aircraft, an incremental center Kalman filter algorithm is proposed to eliminate the adverse effect of system unknown deviation. Firstly, the reason of the system deviation of the target tracking measurement model is understood, and the incremental measurement equation of moving target is established based on the principle of independent increment. Then, aiming at the system model with non-additive noise, an incremental center Kalman filter algorithm is proposed to expand the dimension of process and measurement noise into the state vector. Then, for the system model with additive noise, the algorithm of additive incremental center Kalman filter is derived to reduce the influence of calculation cost and deviation. Deviation factor, finally, consider the various types of incremental algorithm of kalman filtering algorithm and center difference kalman algorithm by MATLAB simulation, the simulation results show that the presented incremental kalman filtering algorithm effectively reduces the maneuvering target tracking in the negative influence of measurement error, improve the target tracking accuracy.

References

[1] Liu X, Yao X, Wang C, et al. Quantum limit of photoncounting imaging based on compressed sensing [J]. Optics Express, 2017, 2015(4): 3286-3296.

[2] Mckerrow P. Modeling the Draganflyer Four-rotor Helicopter [C]. Proceedings of the IEEE International Conference on Robotics and Automation. April, 2004:3596—3601.

[3] ZHANG K, ZHANG L,YANG M H. Real-time compressive tracking [M]// Berlin Heidelberg: Springer, 2012: 864-877.

[4] Chueh-hui. A vision-based tracking algorithm for moving objects and its application in mobile robots [D]; Shanghai: East China University of Technology, 2011

[5] Dalal N, Triggs B. Histograms of oriented gradients for human detection [J]. IEEE Conference on Computer Vision & Pattern Recognition, 2005, 1(12):886-893.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202103_7(3).0055

[6] Baker S, Matthews I. Lucas-Kanade 20 Years On: A Unifying Framework [J]. International Journal of Computer Vision, 2004, 56(3): 221-255.

[7] Hajiyev C, Soken H E. Robust Adaptive Kalman Filter for estimation of UAV dynamics in the presence of sensor/actuator faults [J]. Aerospace Science and Technology, 2013, 28(1):376-383.

[8] Pestana J, Sanchez-Lopez J, Saripalli S, et al. Computer vision based general object following for GPS-denied multirotor unmanned vehicles[C] American Control Conference (ACC). Oregon, USA:IEEE, 2014.

[9] Cynthia. A Study on Ground Target Tracking Technology Technology of Small Unmanned Helicopter Based on Vision [D]; and Tianjin: Nankai University, 2010.