

UAV Velocity Measurement for Ground Moving Target

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Abstract: To satisfy the demand of measuring the velocity of ground moving target through unmanned aerial vehicle (UAV) electro-optical platform, two velocity measurement methods are proposed. Firstly, a velocity measurement method based on target localization is derived, using the position difference between two points with the advantages of easy deployment and realization. Then a mathematical model for measuring target velocity is built and described by 15 variables, i. e. UAV velocity, UAV attitude angular rate, camera direction angular rate and so on. Moreover, the causes of velocity measurement error are analyzed and a formula is derived for calculating the measurement error. Finally, the simulation results show that angular rate error has a strong influence on the velocity measurement accuracy, especially the UAV pitch angular rate error, roll angular rate error and the camera angular altitude rate error, thus indicating the direction for improving velocity measurement precision.

Key words: unmanned aerial vehicle (UAV); target velocity measurement; target localization; velocity measurement error

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0 Introduction

Compared with the manned aircraft, unmanned aerial vehicle (UAV) has the advantages of small size, low cost, convenient operation, low requirement for environment, etc. Therefore, UAV has been widely applied to various fields, including reconnaissance, surveillance, emergency rescue, disaster relief and so on^[1-2].

UAV optical target localization is to calculate the position of ground target with the combination of UAV navigation information, the electro-optical platform pointing angle and the ranging information. Lots of researchers in domestic and abroad have investigated and discussed the new method of UAV target localization and the target localization accuracy improvement^[3-6].

With the development of science and technology, the ground target location can no longer meet the demand of comprehensive and dynamic

information. Therefore, using photoelectric technology to measure the speed of ground targets from the air has become increasingly necessary. In the traditional method, airborne radar, which utilizes the Doppler effect, is adopted to measure the ground target velocity. When a target is close to the radar antenna, the reflected signal frequency will be higher than the transmitter frequency. However, when it is far from the antenna, the reflection signal frequency will be lower than the transmitter frequency. According to the frequency change, the relative velocity of target and radar can be measured^[7]. Hence, the target velocity measurement based on photoelectric technology is superior to the conventional radar velocity measurement thanks to its high sensitivity, easy self stealth and so on. It can be used as an effective supplement to radar velocity measurement.

A novel technology for UAV moving target velocity measurement is proposed in this paper.

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First, a velocity measurement method based on target localization is presented, which is easy to be deployed and realized. Then a mathematical model for measuring target velocity is established, consisting of 15 variables, such as UAV velocity, UAV attitude angular rate, and camera pointing angular rate. Besides, the causes of velocity measurement error is analyzed and the formula is derived for calculating the measurement error. The experimental results show that the method is correct and effective with promising application prospect.

1 System Structure and Coordinate Definition

1.1 Overall system structure

Here, the UAV target velocity measurement system is equipped with GPS, inertial navigation system, and electro-optical platform. Airborne electro-optical platform is installed in the aircraft with upside down. During flight, the position and attitude of UAV always change^[8]. The stable tracking function of electro-optical platform can insulate the jitter of optic axis in inertial space which is caused by UAV attitude motion and other disturbance torque. Image tracker of electro-optical platform will initiate tracking when it finds an interesting target image. It can keep the target in the center of camera view field to realize stable tracking, as shown in Fig. 1.

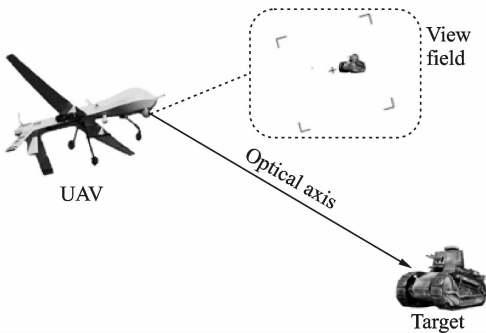


Fig. 1 Target velocity measurement system

1.2 Coordinate definition

First we define the following coordinate systems^[9-11]:

(1) Geodetic coordinate system

In a geodetic coordinate system, the coordinate origin is the earth's center, Z_o axis points to the north direction, and X_o axis to the intersection direction of the Greenwich meridian plane and the earth's equator. In the geodetic coordinate system, the coordinate of each point can be expressed as (B, L, H) , where B , L , H represent latitude, longitude and height of the point respectively.

(2) Geodetic rectangular coordinate system

A geodetic rectangular coordinate system overlaps the geodetic coordinate system. Each point coordinate in the geodetic rectangular coordinates system can be expressed by the projection of the point to each coordinate axis (x_g, y_g, z_g) .

(3) Geographic coordinate system

In a geographic coordinate system, the coordinate origin is the aircraft center. Z_n axis points to the north direction, and X_n axis to the sky, as shown in Fig. 2. In the geographic coordinate system, each point can be expressed as (x_n, y_n, z_n) .

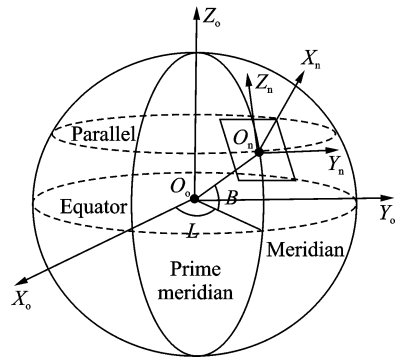


Fig. 2 Coordinate system definition

(4) Aircraft coordinate system

In an aircraft coordinate system, the coordinate origin is the aircraft center. Y_b represents the horizontal axis of the aircraft, and Z_b the vertical axis of the aircraft, X_b points to the back from abdomen of the aircraft. The heading angle, the pitch angle and the roll angle of the aircraft represent the three axis attitudes of the coordinate system relative to the geographic coordinate sys-

tem. When all the attitude angles are zero, the aircraft coordinate system and the geographic coordinate system overlap. In the aircraft coordinate system, coordinate of each point can be expressed as (x_b, y_b, z_b) .

(5) Camera coordinate system

In a camera coordinate system, the coordinate origin is the intersection of camera optical axis and horizontal axis. X_c axis is camera optical axis pointing to the target. The optical axis pointing angle can be expressed by azimuth angle α and elevation angle β .

2 Velocity Measurement Based on Target Localization

Target localization is a process to obtain three-dimensional coordinates of the target. The UAV target localization system can output the coordinates of the target in the geodetic coordinate system, namely latitude, longitude and height.

Given the position data (B_i, L_i, H_i) and $(B_{i+1}, L_{i+1}, H_{i+1})$ of a target at the moment T_i and T_{i+1} respectively, the target position data are transformed to (x_i, y_i, z_i) and $(x_{i+1}, y_{i+1}, z_{i+1})$ in the geodetic rectangular coordinate. The conversion process can be expressed as^[12]

$$\begin{cases} x = (N + H)\cos B\cos L \\ y = (N + H)\cos B\sin L \\ z = [N(1 - e^2) + H]\sin B \end{cases} \quad (1)$$

where N is the radius of curvature in prime vertical, $N = \frac{a}{\sqrt{1 - e^2 \sin^2 B}}$. a is the long radius of ellipsoid, and e the first eccentricity of ellipsoid.

In the interval of $\Delta t = T_{i+1} - T_i$, the average velocity of moving target is

$$v = \frac{\sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2 + (z_{i+1} - z_i)^2}}{\Delta t} \quad (2)$$

Though the method is based on the target localization, which is easy to utilize in the existing target localization system, it does not consider the essence of target localization and introduces

redundant coordinates conversion. The target localization process based on electro-optical platform is shown in Fig. 3, which is essentially a coordinate conversion process from the camera coordinate system to the geodetic coordinate system. During the process, there exists a conversion from the geodetic rectangular coordinate to the geodetic coordinate system. Moreover, in the target velocity measurement process, there is a conversion from the geodetic coordinate to the geodetic rectangular coordinate system. Clearly the above two transformations are redundant, thus bringing forth redundant computing consumption and causing a decline in velocity measurement accuracy.

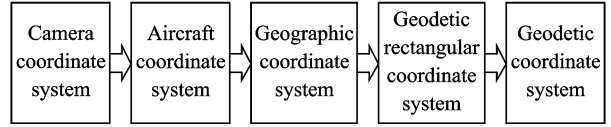


Fig. 3 Process of target localization

3 Target Velocity Measurement Based on Pointing Angle Change

Macroscopically, when the moving target is tracked steadily by UAV, the change of UAV position, attitude and target position is the fundamental reason for the camera pointing angle change. It also shows that the parameters, including UAV velocity, attitude rate, camera pointing angle rate, and target velocity satisfy a mathematical relation, from which the target velocity measuring method can be derived.

In Fig. 4, UAV observes the moving target at P_1, P_2 respectively. M_1, M_2 are the target positions at time T_1, T_2 , respectively. For simplicity, the auxiliary coordinate system $O-X_n Y_n Z_n$ is established, wherein, X_n points to the zenith, Y_n the east, and Z_n the north. $P_1 - X_{n1} Y_{n1} Z_{n1}$ and $P_2 - X_{n2} Y_{n2} Z_{n2}$ are the geographic coordinate systems of P_1 and P_2 respectively. Besides, the axes of coordinate system $O - X_n Y_n Z_n, P_1 - X_{n1} Y_{n1} Z_{n1}, P_2 - X_{n2} Y_{n2} Z_{n2}$ are parallel to each other. Set v_{mx}, v_{my} and v_{mz} as the three-axis components of the air-

craft average velocity in the time interval $\Delta t_1 = T_2 - T_1$. (x_{p1}, y_{p1}, z_{p1}) is the coordinates of P_1 in the $O-X_n Y_n Z_n$; (x_{p2}, y_{p2}, z_{p2}) the coordinates of P_2 in the $O-X_n Y_n Z_n$; (x_{m1}, y_{m1}, z_{m1}) the coordinate of M_1 in the $O-X_n Y_n Z_n$; and (x_{m2}, y_{m2}, z_{m2}) the coordinate of M_2 in the $O-X_n Y_n Z_n$.

$$\begin{cases} x_{p2} = x_{p1} + v_{px} \cdot \Delta t_1 \\ y_{p2} = y_{p1} + v_{py} \cdot \Delta t_1 \\ z_{p2} = z_{p1} + v_{pz} \cdot \Delta t_1 \end{cases} \quad (3)$$

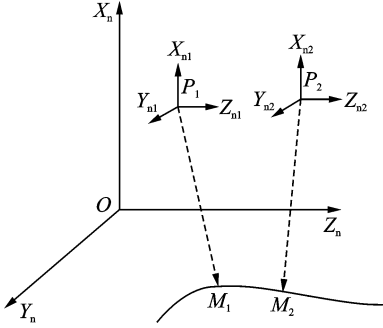


Fig. 4 Principle of target velocity measurement

Let $(x_{nm1}, y_{nm1}, z_{nm1})$ be the coordinates of M_1 in the $P_1-X_{n1} Y_{n1} Z_{n1}$, $(x_{nm2}, y_{nm2}, z_{nm2})$ as the coordinate of M_2 in the $P_2-X_{n2} Y_{n2} Z_{n2}$.

$$\begin{cases} x_{m1} = x_{nm1} + x_{p1} \\ y_{m1} = y_{nm1} + y_{p1} \\ z_{m1} = z_{nm1} + z_{p1} \end{cases} \quad \begin{cases} x_{m2} = x_{nm2} + x_{p2} \\ y_{m2} = y_{nm2} + y_{p2} \\ z_{m2} = z_{nm2} + z_{p2} \end{cases} \quad (4)$$

Combined Eq. (3) with Eq. (4), the average velocity of moving target can be derived in the time interval $\Delta t_1 = T_2 - T_1$.

$$v_{mx} = \frac{x_{m2} - x_{m1}}{\Delta t_1} = \frac{(x_{nm2} - x_{nm1}) + (x_{p2} - x_{p1})}{\Delta t_1} = \frac{(x_{nm2} - x_{nm1})}{\Delta t_1} + v_{px} \quad (5)$$

Thus

$$\begin{aligned} v_{my} &= \frac{(y_{nm2} - y_{nm1})}{\Delta t_1} + v_{py} \\ v_{mz} &= \frac{(z_{nm2} - z_{nm1})}{\Delta t_1} + v_{pz} \end{aligned} \quad (6)$$

Generally, the average velocity of moving target can be written in the time interval $\Delta t_i = T_{i+1} - T_i$ as

$$\begin{cases} v_{mx} = \frac{(x_{nm}^{T_{i+1}} - x_{nm}^{T_i})}{\Delta t_i} + v_{px} \\ v_{my} = \frac{(y_{nm}^{T_{i+1}} - y_{nm}^{T_i})}{\Delta t_i} + v_{py} \\ v_{mz} = \frac{(z_{nm}^{T_{i+1}} - z_{nm}^{T_i})}{\Delta t_i} + v_{pz} \end{cases} \quad (7)$$

When Δt_i is infinitesimal, Eq. (7) can be written approximately as follows

$$\begin{cases} v_{mx} \approx x'_{nm} \big|_{t=T_{i+1}} + v_{px} \\ v_{my} \approx y'_{nm} \big|_{t=T_{i+1}} + v_{py} \\ v_{mz} \approx z'_{nm} \big|_{t=T_{i+1}} + v_{pz} \end{cases} \quad (8)$$

where x'_{nm} , y'_{nm} , z'_{nm} are the derivations of x_{nm} , y_{nm} , z_{nm} at time t , respectively. Thus, the average velocity of moving target is derived in the time interval Δt_i . In Eq. (8), v_{px} , v_{py} , v_{pz} can be measured directly, but x'_{nm} , y'_{nm} , z'_{nm} cannot. However, they can be obtained by calculation.

In the process of UAV target localization, the UAV heading angle ϕ , pitch angle γ and roll angle θ can be acquired by airborne navigation system. The azimuth angle α and the elevation angle β of the camera can be exported by electro-optical platform. At the same time, the distance r between the UAV and the target can be measured from the laser range finder. Accordingly, the target coordinate in the camera coordinate system is $[x_{cm} \ y_{cm} \ z_{cm}]^T = [1 \ 0 \ 0]^T$, and thus the coordinate of target in the geographic coordinate system can be derived by coordinate transformation, as shown in Eq. (9)

$$\begin{bmatrix} x_{nm} \\ y_{nm} \\ z_{nm} \end{bmatrix} = \mathbf{Rot}_b^n \cdot \mathbf{Rot}_c^b \cdot \begin{bmatrix} x_{cm} \\ y_{cm} \\ z_{cm} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & c\phi & -s\phi \\ 0 & s\phi & c\phi \end{bmatrix} \cdot \begin{bmatrix} c\gamma & 0 & s\gamma \\ 0 & 1 & 0 \\ -s\gamma & 0 & c\gamma \end{bmatrix} \cdot \begin{bmatrix} c\theta & -s\theta & 0 \\ s\theta & c\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 \\ 0 & c\alpha & -s\alpha \\ 0 & s\alpha & c\alpha \end{bmatrix} \cdot \begin{bmatrix} c\beta & 0 & s\beta \\ 0 & 1 & 0 \\ -s\beta & 0 & c\beta \end{bmatrix} \cdot \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \quad (9)$$

where \mathbf{Rot}_b^n is the rotation matrix of the aircraft coordinate system to the geographical coordinate system, and \mathbf{Rot}_c^b the rotation matrix of the camera coordinate system to aircraft coordinate system.

$$\begin{cases} x_{nm} = r \cdot c(\gamma) s(\theta) s(\alpha) s(\beta) - r \cdot c(\alpha) s(\gamma) s(\beta) - r \cdot c(\gamma) c(\theta) c(\beta) \\ y_{nm} = r \cdot c(\gamma) c(\alpha) s(\phi) s(\beta) - r \cdot c(\theta) c(\beta) s(\phi) s(\gamma) - r \cdot c(\phi) c(\beta) s(\theta) - \\ \quad r \cdot c(\phi) c(\theta) s(\alpha) s(\beta) + r \cdot s(\phi) s(\gamma) s(\theta) s(\alpha) s(\beta) \\ z_{nm} = r \cdot c(\phi) c(\theta) c(\beta) s(\gamma) - r \cdot c(\beta) s(\phi) s(\theta) - r \cdot c(\phi) c(\gamma) c(\alpha) s(\beta) - \\ \quad r \cdot c(\gamma) s(\phi) s(\alpha) s(\beta) - r \cdot c(\phi) s(\gamma) s(\theta) s(\alpha) s(\beta) \end{cases} \quad (10)$$

$$\begin{aligned} x'_{nm} &= r' \cdot c(\gamma) s(\theta) s(\alpha) s(\beta) - r \cdot s(\gamma) s(\theta) s(\alpha) s(\beta) \gamma' + r \cdot c(\gamma) c(\theta) s(\alpha) s(\beta) \theta' + \\ &\quad r \cdot c(\gamma) s(\theta) c(\alpha) s(\beta) \alpha' + r \cdot c(\gamma) s(\theta) s(\alpha) c(\beta) \beta' - r' \cdot c(\alpha) s(\gamma) s(\beta) + r \cdot s(\alpha) s(\gamma) s(\beta) \alpha' - \\ &\quad r \cdot c(\alpha) c(\gamma) s(\beta) \gamma' - r \cdot c(\alpha) s(\gamma) c(\beta) \beta' - r' \cdot c(\gamma) c(\theta) c(\beta) + r \cdot s(\gamma) c(\theta) c(\beta) \gamma' + \\ &\quad r \cdot c(\gamma) s(\theta) c(\beta) \theta' + r \cdot c(\gamma) c(\theta) s(\beta) \beta' \end{aligned} \quad (11)$$

where $s(\cdot)$ is short for $\sin(\cdot)$ and $c(\cdot)$ for $\cos(\cdot)$. After the expansion and simplification of Eq. (9), Eq. (10) can be acquired. Furthermore, Eq. (11) can be obtained from the derivation of x_{nm} on t . Similarly, the mathematical expressions of y'_{nm} and z'_{nm} are known.

In Eq. (11), the heading angle rate ϕ' , the pitch angle rate γ' and the roll angle rate θ' can be measured by aircraft navigation system, the azimuth angle rate α' and elevation angle rate β' can be measured by the angular velocity sensor of electro-optical platform, and the laser ranging value rate r' can be calculate by two times laser ranging measurement combined with the measurement interval. In practice, the above measurement of each rate should be in a same time period

$$\begin{aligned} v_{mx} &= F(\gamma, \theta, \alpha, \beta, r, \omega_\gamma, \omega_\theta, \omega_\alpha, \omega_\beta, v_r, v_{px}) \approx \{v_r \cdot c(\gamma) s(\theta) s(\alpha) s(\beta) - r \cdot s(\gamma) s(\theta) s(\alpha) s(\beta) \omega_\gamma + \\ &\quad r \cdot c(\gamma) c(\theta) s(\alpha) s(\beta) \omega_\theta + r \cdot c(\gamma) s(\theta) c(\alpha) s(\beta) \omega_\alpha + r \cdot c(\gamma) s(\theta) s(\alpha) c(\beta) \omega_\beta - v_r \cdot c(\alpha) s(\gamma) s(\beta) + \\ &\quad r \cdot s(\alpha) s(\gamma) s(\beta) \omega_\alpha - r \cdot c(\alpha) c(\gamma) s(\beta) \omega_\gamma - r \cdot c(\alpha) s(\gamma) c(\beta) \omega_\beta - v_r \cdot c(\gamma) c(\theta) c(\beta) + \\ &\quad r \cdot s(\gamma) c(\theta) c(\beta) \omega_\gamma + r \cdot c(\gamma) s(\theta) c(\beta) \omega_\theta + r \cdot c(\gamma) c(\theta) s(\beta) \omega_\beta\} |_{t=T_{i+1}} + v_{px} \end{aligned} \quad (12)$$

$$\begin{aligned} \Delta v_{mx} &= \frac{\partial F}{\partial \gamma} \Delta \gamma + \frac{\partial F}{\partial \theta} \Delta \theta + \frac{\partial F}{\partial \alpha} \Delta \alpha + \frac{\partial F}{\partial \beta} \Delta \beta + \frac{\partial F}{\partial r} \Delta r + \frac{\partial F}{\partial \omega_\gamma} \Delta \omega_\gamma + \frac{\partial F}{\partial \omega_\theta} \Delta \omega_\theta + \\ &\quad \frac{\partial F}{\partial \omega_\alpha} \Delta \omega_\alpha + \frac{\partial F}{\partial \omega_\beta} \Delta \omega_\beta + \frac{\partial F}{\partial v_r} \Delta v_r + \frac{\partial F}{\partial v_{px}} \Delta v_{px} \end{aligned} \quad (13)$$

After the previous derivation, the source of target velocity measurement error includes aircraft attitude angle error ($\Delta\phi$, $\Delta\gamma$, $\Delta\theta$), aircraft attitude angle rate error ($\Delta\omega_\phi$, $\Delta\omega_\gamma$, $\Delta\omega_\theta$), camera pointing angle error ($\Delta\alpha$, $\Delta\beta$), camera pointing angle rate error ($\Delta\omega_\alpha$, $\Delta\omega_\beta$), laser ranging value error Δr , laser ranging value rate Δv_r , and velocity error of the aircraft (Δv_{px} , Δv_{py} , Δv_{pz}).

The target velocity measurement error can be obtained by perfect differential. Taking the solution of moving target velocity error on the X axis for example, partial derivative for each variable

to ensure time synchronization.

According to Eq. (11) and Eq. (8), the target velocity is related to the following variables: aircraft heading angle ϕ , pitch angle γ , roll angle θ , camera azimuth angle α and elevation angle β , laser ranging value r , aircraft heading angle rate ϕ' , pitch angle rate γ' , roll angle rate θ' , camera azimuth angle rate α' , elevation angle rate β' , and laser ranging change rate r' . To simplify description, the aircraft heading angle rate ϕ' is defined as ω_ϕ , the pitch angle rate γ' as ω_γ , the roll angle rate θ' as ω_θ , the camera azimuth angle rate α' as ω_α , the elevation angle rate β' as ω_β , and the laser ranging value rate r' as v_r . Therefore, the X axis velocity component of the moving target can be written as

respectively will get Eq. (13). Combined Eq. (12) with Eq. (13), the specific velocity error can be acquired. The solutions of Δv_{my} and Δv_{mz} are the same as that of Δv_{mx} . Thus, the velocity error of moving target can be calculated by Eq. (14).

$$\Delta v_m = \sqrt{\Delta v_{mx}^2 + \Delta v_{my}^2 + \Delta v_{mz}^2} \quad (14)$$

4 Simulation Results

The motion laws of target and aircraft are first established, which are much close to the real condition. Then the target coordinates and air-

craft coordinates can be created. Considering that each measured parameters bring errors in practice, it also need to add different noise to these parameters. Then, using the proposed method, the average velocity of moving targets in different times can be calculated. Compared with the located velocity of moving target in simulation, the correctness and the accuracy of the method is validated.

The simulation condition can be expressed as

$$\begin{cases} x_p = 2000 \\ y_p = 15 + 30t \\ z_p = 55 + 10t \end{cases} \quad \begin{cases} x_m = 10 \\ y_m = 200 + 20t \\ z_m = 400 + 10t \end{cases} \quad (15)$$

where (x_p, y_p, z_p) is the aircraft trajectory and (x_m, y_m, z_m) the target trajectory. It is assumed that the measurement parameter error obeys Gauss distribution. The errors of aircraft attitude angle (heading angle, pitch angle, roll angle) and attitude angle rate are 0.3° and $0.1^\circ/\text{s}$, respectively. The errors of camera pointing angle (azimuth, angular altitude and direction angle rate are 0.02° and $0.01^\circ/\text{s}$, respectively. The error of laser ranging is 5 m, the error of laser ranging rate 5 m/s, and the error of aircraft velocity 5 m/s.

Measuring the velocity every 0.5 s, 100 groups of velocity values be acquired. By repeating simulation calculation of each velocity value for 1000 times, the final measured velocity of the target is obtained. Fig. 5 shows the distribution of measured velocity and actual velocity of the target point duration in 50 s. The measured velocity and actual velocity of moving target are basically coincide, it proves that the target velocity measurement algorithm proposed in this paper can measure the velocity of moving targets effectively.

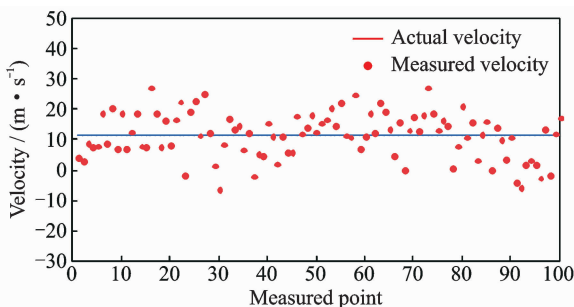


Fig. 5 Simulation results

Furthermore, two simulation are conducted to study the effect of angular rate measurement errors on measurement precision.

(1) With the increasing aircraft attitude angle rate error $(\Delta\omega_\phi, \Delta\omega_\gamma, \Delta\omega_\theta)$ from 0° to 0.5° , the rest of the measurement errors are all zero. The experimental results are demonstrated in Fig. 6. Here, the aircraft pitch angular rate error and roll angular rate error have higher impact on target velocity measurement accuracy. Along with the increase of pitch angle rate error and roll angular rate error, velocity error also increases rapidly. Besides, the influence of heading angle rate error on the target measured velocity accuracy is relatively small.

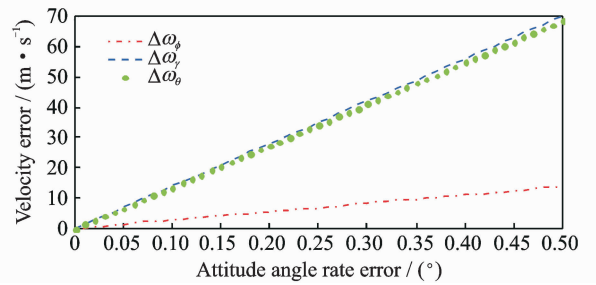


Fig. 6 Relation between attitude angular rate error and velocity error

(2) When the camera pointing angle rate error $(\Delta\omega_\alpha, \Delta\omega_\beta)$ varies from 0° to 0.05° , the rest of the measurement errors are all zero. In Fig. 7, the influence of elevation angle rate error is obviously stronger than the azimuth angle rate error on the target measuring velocity accuracy.

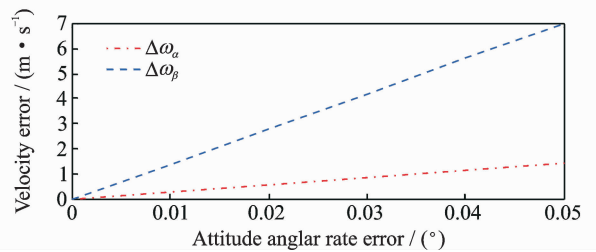


Fig. 7 Camera pointing angular rate error v. s. velocity error

From the two experiments mentioned above, the following conclusions can be drawn. In the process of UAV target measured velocity, angle rate measured error $(\Delta\omega_\phi, \Delta\omega_\gamma, \Delta\omega_\theta, \Delta\omega_\alpha, \Delta\omega_\beta)$

has larger effect on the target measuring velocity accuracy, especially the aircraft pitch angle rate error $\Delta\omega_\gamma$, the roll angular rate error $\Delta\omega_\theta$, and the camera elevation angle rate error $\Delta\omega_\beta$. Therefore the increase of measuring precision of angular rate is an effective way to improve the measurement accuracy of target velocity.

5 Conclusions

Two methods using electro-optical platform of UAV are proposed for velocity measurement. First, an easy velocity measurement method based on target localization is derived, using the position difference between two points. Then a mathematical model for measuring target velocity is established based on 15 variables, including UAV velocity, UAV attitude angular rate, camera pointing angular rate and so on. Besides, the causes of velocity measurement error are analyzed and a formula is derived to calculate the measurement error. The experimental results show that it is feasible and effective to use electro-optical platform and UAV navigation data in velocity measurement of moving target, which provides a new approach to velocity measurement of UAV relative to ground target.

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