Attitude Parameters Extraction of UAV Based on Hybrid Computer Vision and Improved Artificial Bee Colony Algorithm

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Abstract: In this paper, we proposed a hybrid method in extracting the attitude parameters of unmanned aerial vehicle (UAV), which is based on computer vision and improved artificial bee colony (ABC) algorithm. Horizon is used as a characteristic line, whose two parameters, Φ and σ are utilized to obtain UAV's parameters: roll angle ψ and pitch angle θ. Defogging Algorithm is used to make the original pictures clearer and gain the transmission image for horizon abstraction. The UAV could obtain the horizon through improved ABC independently. We also analyzed the relationship between line parameters and UAV parameters and calculated the UAV parameters. Experimental results verified the feasibility and effectiveness of our presented approach.

Key Words: unmanned aerial vehicle (UAV), computer vision, artificial bee colony (ABC), horizon

1 Introduction

In 1915, Siemens Company in Germany developed a glide bomb by utilizing servo control system and command guidance, and was regarded as the pioneer of control for unmanned aerial vehicle (UAV) [1]. UAV was gradually known to the public and caught more attention as several neoteric wars broke out. Afterwards it extended from the military domain to civil cases. UAV can be used as aerial reconnaissance platform and weapon platform in the military fields. In addition, UAV can also engage in precision strike, bombing, intercepting tactical missile. Even to operate under special conditions instead of human beings. UAV can be used in field monitoring, meteorological sounding, high-way patrol, exploration survey, flood monitoring, aerial photography, traffic control, power line inspection, prevention and rescue for forest fire in the civil fields. Although UAV has achieved rapid progress in recent years, reliable launch and recovery still remains to be the main problem.

Computer vision [2]-[3] includes methods for acquiring, processing, analyzing, and understanding high-dimensional data from the real world to achieve numerical or symbolic information in images [4]-[6]. Computer vision [7]-[8] has wide applications in robots, industry and other fields.

We usually cannot get an ideal result when utilizing traditional image enhancement method to solve practical problems. Therefore, a series of new methods were put forward by scholars. It can be summarized from specific applications that image enhancement methods based on spatial and frequency domain mainly work around the local and global.

D. Karaboga succeeded in solving numerical optimization problems by utilizing bee foraging theory and put forward ABC algorithm systematically in 2005. H. B. Duan has also

applied the ABC to constrained numerical optimization and path planning problems[9]-[10].

In combinatorial optimization problems, Chin Soon Chong, Malcolm Yoke Hean Low and some other ones solved the job shop scheduling problem with ABC.

2 DEFOGGING ALGORITHM

2.1 Model

In computer vision and computer graphics, the model [11] that is widely used to describe the formation of a hazy image is given as

$$I(x) = J(x)t(x) + A(1 - t(x)) \tag{1}$$

where $I(x)$ is the observed intensity, $J(x)$ is the scene radiance, A is the global atmosphere light, and $t(x)$ is the medium transmission describing the portion of the light that is not scattered and reaches the camera. The goal of haze removal is to recover $t(x)$ from $I(x)$.

2.2 Estimating the Transmission A

We obtain the $I_{dark}(x)$ through formula (2). The top 0.1% pixel value has the corresponding locations in the picture $It(x)$. The value of A is the maximum of the pixel values in those positions.

There is a need to explain that A is not the maximum pixel value of the whole $It(x)$.

2.3 Estimating the Transmission "$t(x)$"

Dark Channel Prior has been introduced by which we can obtain t(x). Firstly, we obtain the dark channel image I_{dark}:

$$I_{dark}(x) = \min(\min(It(x))) \tag{2}$$

Each pixel in $It(x)$ equals to the minimum of the RGB in every pixel of the original image.

$$t(x) = 1 - \omega * I_{dark}(x). / A \tag{3}$$

where ω is an experience value [11]. We fix it to 0.9 for all the results presented in this paper.
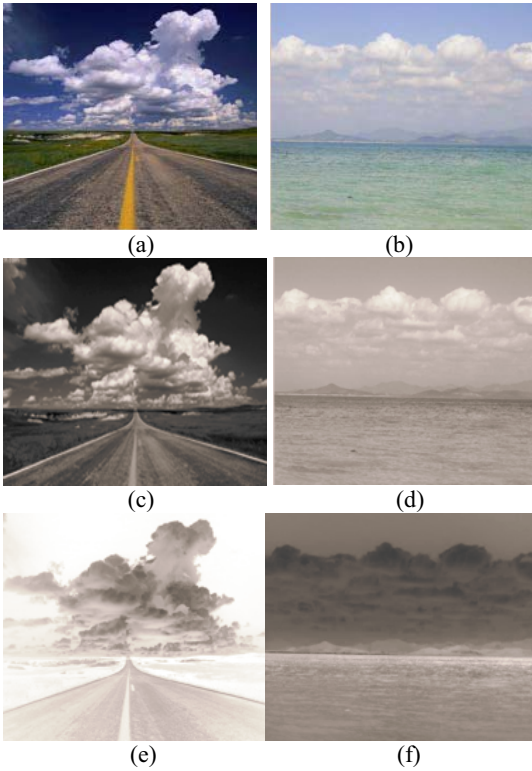
Fig.1. Original images are shown in the first row. Gray images are shown in the second row. The transmission images are shown in the third row.

In the transmission images, the part where the horizon exists has a very different gray value, and this is important in horizon extraction.

3 HORIZON EXTRANCT BY UTILIZING ABC

3.1 Characters of horizon

Horizon divided the picture into two parts as a boundary. The average values of the two parts can be very different [1]. The pixels of sky that is above the horizon are bigger, while the pixels of ground above the horizon are relatively smaller. So, for each line extracted, we can calculate the average values for pixels of the line above and the one below and get the difference value of them as G. It is the characteristic value of this line. G is an $N*1$ matrix, N is the number of the lines extracted. $G(i)$ is the ith line's characteristic value. The line corresponding to the maximum element of G is the horizon we need. The method for calculating $G(i)$ will be presented in 3.2

3.2 Calculation of G

Three main steps are needed for the calculation of G. Firstly, it needs to find the slope and intercept; Secondly, figure out the horizontal and vertical coordinates of every pixel in this line. Finally, calculate the average value of these pixels.

The method mentioned above can be very time consuming in calculation and does not satisfy the timeliness requirement in UAV landing. To solve this problem, we propose a new method that is shown as follows.

If we rotate the image for an angle, the slope and the intercept then become useless. The above calculation changes into computing the average value of these pixels in every row. Afterwards, calculate the difference value of the

row above one row and the one below it starting from the second row. Thus the calculation process becomes simpler and helps saving time. We use the map to illustrate in Fig. 2.
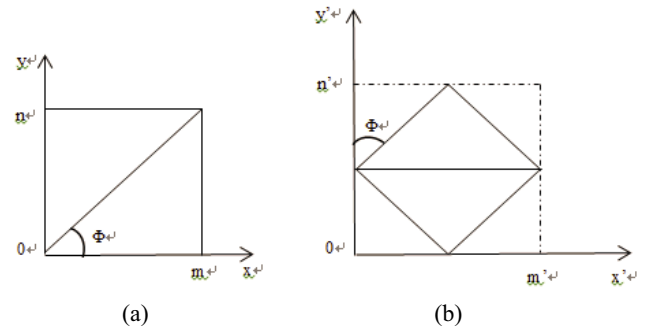

Fig.2. In (a), m is the row number of $t(x)$ and n is the column number. Φ is the intersection angle of line and x-axis. In (b), m' is row number of the new image after rotation and n' is the new column number.

The line turns into a horizon in Fig. 2(b). A cluster of lines with the same slope all turn into the horizontal direction. For the ith line " $L(i)$ ", its characteristic value is:

$$G(i) = (mean(L(i-1)) - mean(L(i+1))) / std2(L(i)) \qquad (4)$$

The mean function is a built-in function in MATLAB. We make no gusher in this paper.

Obviously, it only need one circulation then the matrix G is obtained. Afterwards, by utilizing the max-function we can get the maximum of G named Gm. For another turning angle Φ, we can gain another Gm in the same way. Every Gm has a corresponding turning angle Φ. What we need to do is find the maximum of Gm, and the corresponding Φ is the angle we desire for the UAV parameters.

3.3 Improved ABC

In Section 1, we have presented the ABC development situation briefly. In this section, we will make a further introduce.

Set Φ is positive in counterclockwise direction and negative in clockwise direction. In the program, "Foods" taking different values means that the Φ taking different values. So leader bee Foods we can set through the formula below:

$$Foods = (-90) * rand(1) + 89 * rand(1) \qquad (5)$$

By utilizing the function "imrotate", the image turning can come true. Revenue function is the most important. For every leader bee, which is the value of the Foods, the line's characteristic value function is the revenue function. The method calculating the characteristic value has been introduced in Section 3.1.

The initial parameters in this experiment are given in Table 1.

Np	20
Foodnumber	10
Limit	100
Maxcycle	2500
Ub	ones (1,100)*100
Lb	ones (1,100)* -100
Runtime	1

Globalmins	zeros (1,2500)

Table 1: Initial parameters

4 OBTAIN THE UAV PARAMETERS

4.1 Estimation of σ

The parameter σ is the proportion of the area above the line and the area below the line in the *m*n* image shown in the Fig. 2 (a). From ABC, we can obtain the Φ.

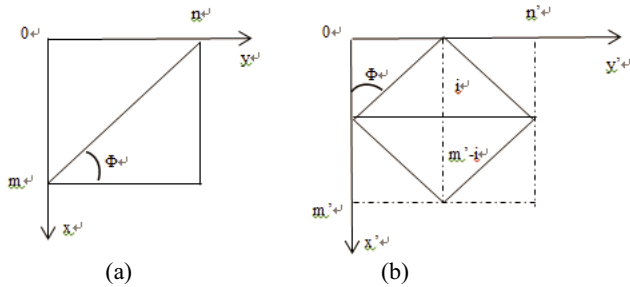
(a)   (b)

Fig.3. In (a), *m* is the line number of $t(x)$ and *n* is the colume number of t(x). In (b), *m'* is new line number of $t(x)$ after rotating and *n'* is new colume number of $t(x)$ after rotating. "*i*"is the row number the line locates.

Firstly, we should judge if *i* is bigger than $m'-i$. If i is bigger than $m'-i$, use the $m'-i$ to calculate. Similarly, if $m'-i$ is bigger than *i*, use *i* to calculate. If $m'-i$ equals to *i*, σ equals to 0.5. In this section, two cases are considered as follows.

Case 1: When *i* is greater than $m'-i$, we can get σ by using the following formula:

$$\sigma = 1 - \frac{1}{2}((m'-i)^2 \tan(\phi) + ((m'-i)^2)/(\tan(\phi)))/(mn)$$

(6)

Case 2: When *i* is less than $m'-i$, we can get σ by using the following formula:

$$\sigma = 1 - \frac{1}{2}(i^2 \tan(\phi) + (i^2)/(\tan(\phi)))/(mn)$$

(7)

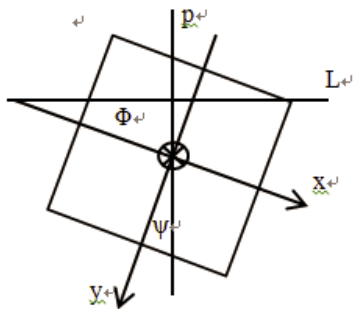### 4.2 The calculation of the roll angle ψ

Fig.4. ψ is the roll angle of UAV and ϕ is the line rotation angle *x-y* is plane coordinate system. *L* is the horizon. *P* is the plumb line[11]
From Fig. 4, we have:

$$\psi = \phi \qquad (8)$$

The camera is fixed on the plane. The camera coordinate system is equivalent to plane coordinate system. If there is only translation relation between the camera coordinate system and the plane coordinate system, they are equivalent.

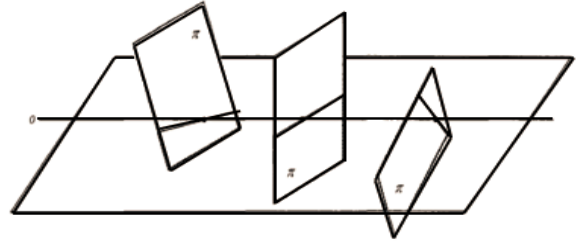### 4.3 Calculation of pitch angle θ

Fig.5. different positions in different σ.[1]

When optical center is fixed, image plane moves following the movement of the optic axis. The movement of optic axis can be divided into three parts: optic axis's rotation in the level, optic axis's rotation in the vertical plane and optic axis's rotation.

For the first case, the position of the horizon is constant. So we considerate the following two circumstances only. For the second case, we set: f is the focal length of the camera, *d* is the distance of horizon and center line in pixels (d will be approximately away), *h* is the height of UAV, *r* is the radius of the earth, *d'* is the physical length of every pixel[1]. It is decided by the camera parameter and it is constant. We can get θ by following formula:

$$\theta = \arctan((d*d')/f) - \arctan(r/(r+h)) \qquad (9)$$

Then, considerate the third case at the same time, we can obtain θ by following formula:

$$\theta = \arctan(((\sigma - 0.5)*m*d')/f) - \arctan(r/(r+h))$$

(10)

Considering that the UAV starts landing in the 300 meters to 500 meters in height, so the second item on the right side can be approximated to 0.7. We get the final for-mula for *θ*:

$$\theta = \arctan(((\sigma - 0.5)*m*d')/f) - 0.7 \qquad (11)$$

5 Experimental results

5.1 Contrast of transmission images and gray image

(a)   (b)

(c)   (d)

Fig.6. The first row shows the gray images. The second line shows transmission images

Fig. 6(a) and (c) are the gray images, Fig. 6(b) and (d) are the transmission images. The transmission image has the better gray value than the gray image in the exact part where exists the horizon. In the transmission image, the part above the horizon and the part below have a more different gray value those in the gray image.

Hence, using the transmission image to extract the horizon is a reasonable method.
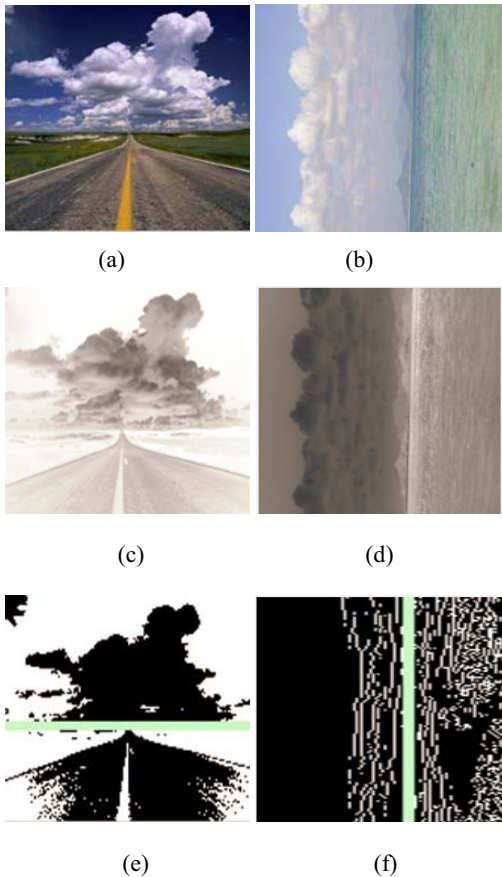
5.2 Horizon extraction results

(a)   (b)

(c)   (d)

(e)   (f)

Fig.7. Line drawn in the filtered image of transmission pictures.

Fig. 7(a), (c) and (e) show the results when the Φ is closed to zero degree, Fig. 7(b), (d) and (f) show the results when the Φ is closed to 90 degree. It is obvious that the results are consistent with the actual situation. Hence, the method proposed in this paper in horizon extraction is practical.

6 Conclusions

In this paper, we proposed a novel method in extracting the attitude parameters of UAV. We start from the picture, using computer vision and the improved ABC to get line parameters of the horizon and through which we get the roll angle and the pitch angle of the UAV. Series of experimental results have verified the feasibility and effectiveness of our presented method.

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