Runway Detection and Tracking for Unmanned Aerial Vehicle Based on an Improved Canny Edge Detection Algorithm

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***Abstract*—A new method based on an improved canny edge detection algorithm for the runway detection and tracking was presented in this paper. Though the traditional Canny Operator has high edge detection capability, it still can be interfered by grave image noise, as its detection accuracy cannot reach single pixel. This paper presented one method that combined Canny Operator with mean filter to represent the runway edge accurately. Then Hough Transform and Chain-Code was used for runway tracking. Experimental results show that this method can have better detection and tracking effect, besides the processing speed is also improved, that laid a favorable foundation for UAV visual navigation.**

Keywords-runway detection and travking; UAV; Canny opertator;visual navigation; image processing

I. INTRODUCTION

Autonomous flight is the focus of UAV research field and how to achieve autonomous flight especially the automatic landing of UAV needs to be solved urgently[1]. Automatic landing of UAV refers that UAV achieves orientation and navigation relying on airborne navigation equipment and flight control system solely, and finally lands safely.

UAV visual navigation refers that we estimate the flight state and situation of UAV by processing images taken by airborne camera using algorithm based on computer vision, and finally achieve accurate automatic landing of UAV[2]. In this process runway detection and tracking is especially important. Usually the control system manipulates UAV to touch down accurately according to the positional information provided by the visual navigation system and also its course and Position parameters. Paper [3] presents a method based on the maximum entropy theory for runway detection and paper [4] presents a method based on template matching [3-4].This paper presented a method based on an Improved Canny Edge Detection Algorithm and Chain-Code for runway detection and tracking. The result presented that this method can get a better accuracy with higher computing efficiency, and it applies a favorable method for UAV automatic landing.

II. ALGORITHM THEORY OF RUNWAY DETECTION AND TRACKING

The boundary of UAV runway has a strong characteristic that it always presents as straight lines in the picture, no matter the picture is translated, rotated, or zoomed. And according to this characteristic, the runway detection can be divided into two steps and they are edge detection and boundary describing. The following is flow chart of runway detection and tracking.

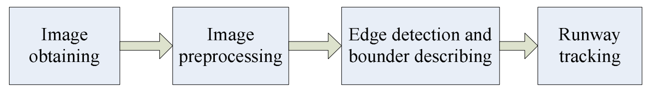

Figure 1. Flow chart of runway detection and tracking.

A. Image Obtaining

This part we get digital image signals through the CronosPlus[5] directly, and we should pay attention to the coordination between image obtaining and processing speed. Here the computer did not process all frames, instead it accepted a new frame only if the CPU was free.

B. Image Preprocessing

Image preprocessing includes image graying, noise abatement and segmentation[6]. In this paper we use the method of weighted average values to get gray images and it is the basic method. Then we use Wiener Filter for noise abatement, considering filtering effect and filtering time. The principle of Wiener Filter[7] is to find $f^{'}$ that can let statistical error function $e^2 = E\{(f - f^{'})^2\}$ to be the minimum value. Here E refers to the expectations operator and f refers to images without degradation. This function can be expressed as the following expression in the frequency domain.

$$F(u,v) = [\frac{1}{H(u,v)} \frac{|H(u,v)|^2}{|H(u,v)|^2 + s[S_n(u,v)/S_f(u,v)]}]G(u,v) \tag{1}$$

In the equation above, $S_n(u,v)/S_f(u,v)$ was called as Signal to Noise Ratio, and SNR for short. we can find that if all the values about u and v are corresponded, the noise power spectrum is zero, then $S_n(u,v)/S_f(u,v)$ is zero. Then the Automatic Threshold algorithm was chosen for image segmentation in this paper. It is a classical algorithm which takes use of the grayscale difference between the target and its background to decide each pixel belongs to the target or the background.

C. Edge Detection and Boundary Describing

1) Canny edge detection operator

Canny operator was put forward in 1986, which is based on optimization algorithm. It has been used widely as it has a

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favorable SNR and a good detection precision. Here are the steps of canny operator.

Firstly, use Gaussian Filter for image smoothing and Gaussian function is as following:

$$H(x,y)=e^{-\frac{a^2+b^2}{2\sigma^2}} \quad (2)$$

$$G(x,y)=f(x,y)*H(x,y) \quad (3)$$

Secondly, calculate gradient amplitude and direction based on the finite difference with first order local deviation.

Thirdly, do the non-maxima suppression of gradient amplitude.

Lastly, use dual-threshold algorithm to detect and connect edge.

2) Hough transform for boundary representation

In this paper Hough transform was used for fitting straight lines combined with least square method. Suppose the set of data points is $M=(x_i,y_i)^T,(i=1,2,3......n)$, here n refers to the number of data points. Suppose data of M is distributed around R straight lines, and according to the experimental purposes, we have given error threshold as d_k.

a) Hough transform: In this part, our paper applied Hough transform to M, using the fractional look-up table method. Then we can get parameters of the line that we want to get, and we defined them as (a_k,b_k). After that, it is easy to get slope intercept form of the line, which is expressed as the following:

$$y_i=a_kx_i+b_k \quad (4)$$

b) Find out data points M_k^* and calculate the distance of M to the line determined by equation (4) :

$$d_{ki}=\frac{|a_kx_i+b_k-y_i|}{\sqrt{1+a_k^2}} \quad (x_i,y_i)\in M \quad (i=1,2...n.k=1,2...n) \quad (5)$$

If $d_{ki}<d_k$ then we can get

$$(x_i,y_i)\Rightarrow M_k^*(x_{kj},y_{kj}),(j=1,2,3...n^*,n^*\le n)$$

Here M_k^* was the set of data points around the line k, which corresponded with the error threshold requirements.

3) Determain the interval of each straight line segment:

Here lines are fitted based on M_k^*, then we can get the parameters of line equations, they are (a_k^*,b_k^*). Then we can get the intervals of all line segments, that is

$$y_{kj}=a_k^*x_{kj}+b_k^* \quad (x_{kj})_{\min}\le x_{kj}\le (x_{kj})_{\max} \quad (6)$$

D. Chain code method for contour tracking

In this part, the whole process of tracking control is as follows:

First start from the track starting point of region boundary, second call the subroutine for finding the next boundary point to search the next boundary point successively , until it is found and its chain code was put into the chain code chart. Then set this point as the current boundary point, and get the chain code of new detection starting point. So that it is coming into the next round of boundary search, and this cycle would continue until the track end. Here we should pay attention to that when the next boundary point has already found, the starting point for following-up process should be determined[8]. Usually a point outside the region was defined as the starting point.

III. THE IMPROVED CANNY EDGE DETECTION ALGORITHM

It can be found form the traditional canny edge detection algorithm that it has may shortcomings, and we conclude as follows:

- Traditional operator got the gradient amplitude by calculating the finite-difference mean of neighborhood. That let it is sensitive to noises and easy to detect false edges or missing some real edge in detail.
- Traditional canny operator used dual-threshold method for edge positioning. It is difficult to decide the lower threshold suitably. If it is too large then it is hard to locate all of the edge and easy to Appear discontinuous. On the contrary if it is too low, many false edges may appear.

So this paper put forward an improved canny edge detection algorithm aimed at these problems, and it has two key points:

A. Use K near mean filter instead of Gaussian filterfor image smoothing.

In this paper we used K near mean filter[9] for image smoothing, and this method can remove noise while preserving edge of the gray scale characteristics, that will not result in fuzzy image edge. The specific steps of this algorithm are as follows:

- Make a $N\times N$ template, using the pending pixel as the center. Here N is an odd number and in this paper its value is 5.
- Select some pixel points, that their gray has smallest difference with the gray of the pending pixel. Then calculate their average value and use it instead of the original center point pixel value. Here we defined the number of these points as K . In this paper the value of K is 5.

B. Four thresholds method for edge detection and location

In order to solve the problem that it’s difficult to decide proper thresholds, when we use method of dual-threshold[10], in this paper four thresholds method was used. The specific steps are as follows:

- Set the larger and lower threshold values according to the proportion that marginal point accounts for the gradient modulus maxima. And the larger value is expressed as t_{top}, the lower value is t_{down}.
- Choose the maxima of points which are larger than t_{top} as the edge starting point.
- Keep local modulus maxima which are larger than t_{down} and connected with edge starting point. Delete local modulus maxima that are lower than t_{down} or cannot be connected. Then we can get a generalized edge chain.
- Pre-set thresholds of the edge chain: t_n and $t_{average}$, and $t_{down} < t_{average} < t_{top}$. Then delete generalized edge chain, if its length is less than t_n or its average value of local modulus maxima is lower than $t_{average}$. So that the image edge is got.
- Finally we must pay attention to one point in this method, that is we should value t_{down} and $t_{average}$ properly. The value of t_{down} should be as small as possible in order to get all the possible edge points. And the value of $t_{average}$ should be close to t_{top}, or it would be difficult to delete false edges.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

In our experiment, we build a simulation of UAV shooting scene, and design the runway to be a cross. This paper mainly had image filtering, segmentation, edge detection and boundary tracking for an image. Here we take one specific paper for results analysis.

Figure 2 is the comparison of the original image and the filtered image:

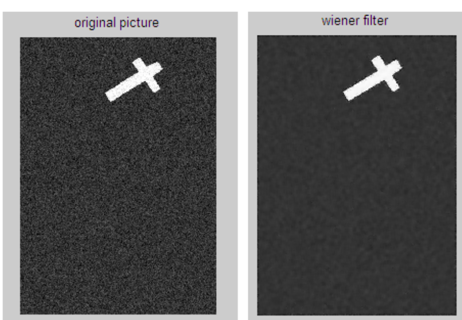

Figure 2. The comparison of original image and filtered image

We can see from figure1 that the filtered image is obviously smooth than the original image. So that the Wiener Filter has a good filtering effect in this experiment.

Then figure 3 is the result comparison of traditional canny operator and improved canny operator.

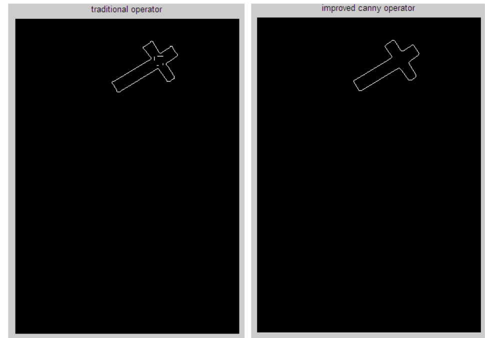

Figure 3. Result comparison of traditional operator and improved operator

From figure 3, we can see that the edge detection effect of improved canny operator is obviously better than traditional canny operator. Actually the improved canny operator cannot only improve the detection precision of filtering false edge, but also keeps the advantages of traditional algorithm that is simple and high efficiency.

Then the next step is boundary tracking, we get the edge chain code, the result is as following:

0000776776767776777001000100010001000001
001000000100010001000007676666445444454444
544544445444454444544445444457767677677
6767666544444433233232332332323323233332
32333233232222001.

V. CONCLUSION AND PROSPECT

In the UAV automatic landing process, runway detection and tracking in very important, so we did many researches about this field, and put forward the above method for runway detection and tracking. Experimental results show that our method is favorable for runway tracking, and the edge detection effect of improved canny operator is better than the effect of traditional canny operator. This feasibility of this method provided a good foundation for UAV automatic landing based on visual navigation.

Our research about runway detection and tracking was expected to be applied for the "China Aviation Industry Cup - International Unmanned Aerial Vehicle Innovation Grand Prix". Although this study did not used in this competition finally, it still made a useful attempt to win this tournament. If this research can be used to practical applications, it is will play an important role for the automatic landing of our fixed-wing UAV airborne magnetic measuring system. Figure3 is my lab's experiment situation.

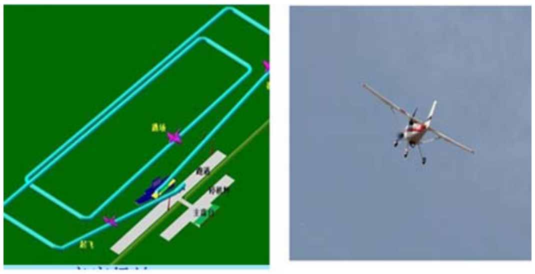

Figure 4. Competition site and actual flight test

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REFERENCES

[1] Lu C-P, "Fast and Globally Convergent Pose Estimation from Vedio Images," Transactions on Parten Analysis and Machine Intelligence ,Vol.22,2000, pp. 610–622.

[2] Ling Bo, Wu Jing, and Xiuqing Ye, "The application of the maximum entropy principle for road detection," Journal of Circuits and Systems, pp.78–81, October2005.

[3] Srikanth Saripalli, James F.Montgomery and Gaurav S.Sukhatme. Vision-Based "Autonomus Landing of an Unmanned Aerial Vehicle, Preceeding of IEEE," International Conference on Robotics and Automation , 2002, pp. 2799–2804.

[4] Ding Meng, CAO Yun-feng, GUO lin, A Method to Recgonize and Track Runway in the Image Sequences Based on Template Matching, International Symposium on Systems and Control in Aerospace and Astronautics , pp.68–73, 1218-1221, 2006.

[5] O.D.Faugeras, "Three-Dimensional Computer Vision: a Geometric," MIT Press, Cambridge, MA, 1993.

[6] C.S.Sharp, Omid.Shakernia, S.Sastry, "A Vision System for Landing an Unmanned Aerial Vehicle," Preceeding of IEEE ICRA, pp.1720–1727,2001.

[7] Omid Shakermia, Rene Vidal, Sourtney S Sharpy , "Multiple View Estimation Motion and Control for Landing an Unmanned Aerial Vehicle," IEEE Conference on Robotics and Automation ,2002, pp. 2793–2798.

[8] Liu Xinghua, Cao Yunfeng, "Research on the Application of Vision-based Autonomus Navigation to the Landing of the UAV", 5th International Symposium on Instrumentation and Control Technology. Beijing,China,2003,pp.385–388.

[9] Vapnik V N, "Estimation of Dependencies Based on Empirical Data Berlin"Springer-Vrlage,1982.

[10] Andrew Miller, Mubarak shah, Don Harper. "Landing a UAV on a Runway Using Image Registration[C]" IEEE International Conference on Robotics and Automation, 2008, PP.182-187.