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An Improved Vision-Based Algorithm for Unmanned Aerial Vehicles Autonomous Landing

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Abstract

In vision-based autonomous landing system of UAV, the efficiency of target detecting and tracking will directly affect the control system. The improved algorithm of SURF(Speed Up Robust Features) will resolve the problem which is the inefficiency of the SURF algorithm in the autonomous landing system. The improved algorithm is composed of three steps: first, detect the region of the target using the Camshift; second, detect the feature points in the region of the above acquired using the SURF algorithm; third, do the matching between the template target and the region of target in frame. The results of experiment and theoretical analysis testify the efficiency of the algorithm.

Keywords: autonomous landing, camshaft, color histogram, SURF

1.Introduction

Recently, the applications of unmanned aerial vehicles are diverse, ranging from search and rescue, reconnaissance and surveillance. GPS/INS navigation system is mainly used in the last ten years. But signals from the net of the GPS are useless in particular environment. The classical navigation system assisted by GPS does not equal to the requirement of autonomous navigation in the mixed environment [1,2]. Vision aided autonomous navigation system has been extensively explored in these years.

In vision aided autonomous navigation system autonomous landing is important. There are a lot of ways to recognize the helipad, [3,4,5] use standard image processing algorithms to realize the recognition. It will get the relative position of the target in the image by the way of binary processing, filtering, erosion and dilation of the gray image which is changed from a color image. After that the information of UAV is got by algebra transforming. The vision aided autonomous landing system will be achieved finally. Pattern recognition method was used to recognized the helipad by Lin Feng etal[6]. Zernike moments[7] were used to recognize the helipad [8]. The appearance of the SIFT(Scale Invariant Feature Transform)[9] provides an important method for helipad recognization and tracking. SIFT has the property of repeated

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and robust, so it is widely used in computer vision including UAV and vehicles on board [10]. SIFT algorithm was also used to image registration [11]. In navigation the robots predict the position of SIFT feature points using dead-reckoning [12]. Templeton etc [13] used SIFT algorithm to track feature points. For the stability and efficiency of the SIFT Katzourakis etc [14] used this algorithm to realize the vision based navigation system of UAV.

After the appearance of SIFT researches have done improvement. For example Ke and Sukthankar [15] put forward the PCA-SIFT which is based on SIFT. As SIFT, the descriptors encode the salient aspects of the image gradient in the feature point's neighborhood. They apply Principal Components Analysis (PCA) to normalized gradient patch. Bay etc put forward SURF [16]. SURF as SIFT is also applied in feature points detection and image matching. SURF includes the sign of Laplacian, i.e. it allows for a quick distinction between bright features on a dark ground and dark features on a bright background. SURF is more robust than SIFT in feature points detection and tracking. However SURF is burden by computational weight according to the hardware of the UAV. In order to improve system security and computational efficiency we not only employed SURF, but also used Camshift algorithm (Continuously Adaptive Mean-SHIFT [17]). We used the Camshift algorithm to tracking the helipad and gave the region of it. After that we used SURF to detect the feature points in targets image and the region of target as the above. We used the improved algorithm to do the feature points matching and tracking.

2.Hardware construction

Our experimental test-bed Thunder Tiger is a gas-powered helicopter which is fitted with a PC-104 stacked with several sensors as figure1. IMU is composed of three axis accelerometers and three-axis gyroscopes which provide the state information to the on board computer. The IMU was produced by Rotomotion. The helicopter is also equipped with a color CCD camera and ultrasonic sonar which is a series of Polaroid 600. The ground station is a laptop which is used to communicate with PC-104. Communication is carried by wireless Ethernet.

Figure 1: Thunder Tiger

3.Vision Algorithm

The overall vision algorithm strategy is as Figure 2.

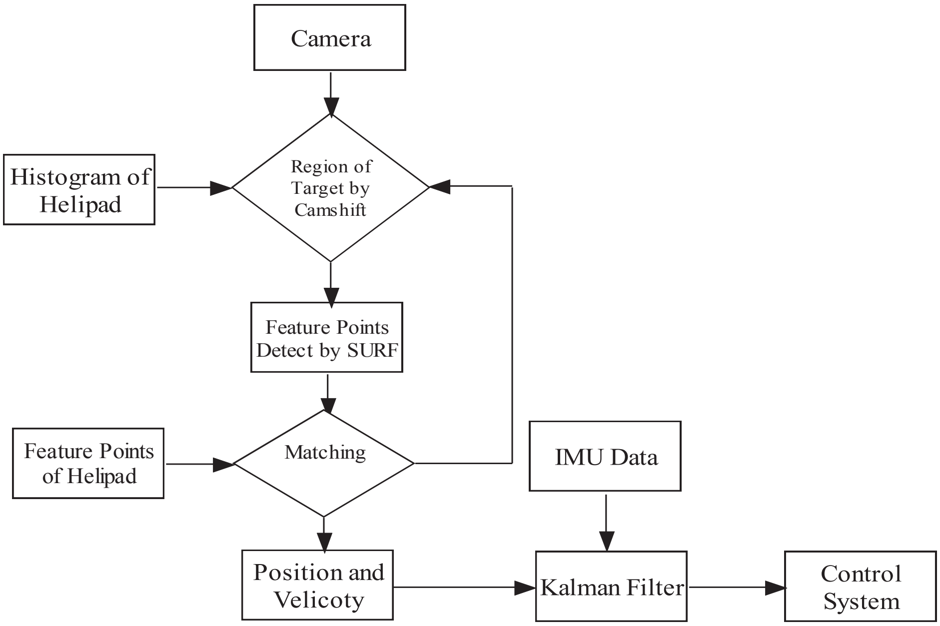

Figure 2: The flow char of the vision aided UAV autonomous landing

3.1.Helipad Region Determined by Camshift

Camshift algorithm was used in object tracking based on the color information of the moving target. This algorithm was divided into three steps:

- Calculation of Target Histogram

H component of the HSV model denotes the color information. Camshift algorithm is sensitive to color information. It is necessary to change the color image captured by camera from RGB color space to HSV. In experiment we chose a green image as a target. The histogram of the image in color space is as figure 3.

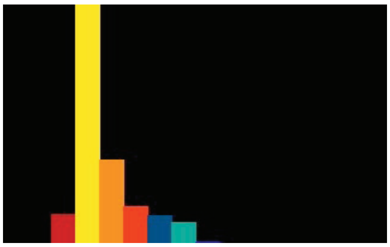

Figure3: Color Histogram of Target

- Background Projection

According to the color histogram the target was changed to color probability distribution and matched between the color probability distribution image and the image captured by camera. This process is background projection.

- Camshift Algorithm

Camshift employing the Mean-Shift [17] firstly detected the center of the target, and then calculated the scale and orientation. This process applied in continuous images was called Camshift. The basic idea of the algorithm is that all frames of the video calculated by Meanshift. The results of previous frame (the center and size of Search Window) were used in the next frame as initial value of the search window.

Target tracking was realized by cyclic iteration as the above. The algorithm was divided into five steps:

Step 1: Define the image as searching area;

Step 2: Initialize the size and position of the search window;

Step 3: Calculate the color probability distribution of the search window, this region should be bigger than the search window;

Step 4: Execute the MeanShift algorithm to get the new position and size of the search window;

Step 5: Apply the results of the step 3 to initialize the position and size of the search window in next frame, switch to step 3 and continue.

Figure4:Tracking Effect

Tracking effect based on color histogram is as Figure 4.

3.2.SURF Algorithm

H.Bay etc put forward the SURF algorithm based on SIFT in 2006 [16]. SIFT algorithm was summarized as follows: (1) Selection of extreme value points in scale space：Search for local extreme value in serials of difference of Gaussian image and construct the Gaussian pyramid; (2) Location of feature points: Locate the feature points in sub-pixel and discard unstable extreme value points. (3) Distribution of orientation: Identify the principle direction of each feature point in local area. (4) Descriptors of feature point: Construct local descriptors of each feature point. This descriptor was based on local gradient. The SURF algorithm had multi-dimension descriptors as descriptor length 64, SURF-128, and U-SURF (where the rotation invariance of the interest points have been left out, descriptor length is 64). The detector is based on the Hessian matrix, but uses a very basic approximation, just as DoG (Difference of Gaussian) [9] is a very basic Laplacian-based detector. It relies on integral images to reduce the computation time and we therefore call it the ’Fast-Hessian’ detector. The descriptor, on the other hand, describes a distribution of Haar-wavelet responses within the interest point neighborhood. Moreover, only 64 dimensions are used, reducing the time for feature computation and matching, and increasing simultaneously the robustness. It also presents a new indexing step based on the sign of the Laplacian, which increases not only the matching speed, but also the robustness of the descriptor.

SIFT/SURF using Hessian matrix to get the local extreme values of image was stable. But the calculation of principle direction was over-dependence on the gradient direction of the local pixel. In this situation the principle direction we got was wrong. The feature vector extraction and matching was over-dependence on the principle direction. Despite this less error may cause the amplified error or the failure of feature matching. Otherwise the levels of image pyramid were not enough will cause scale error. The latter feature vector extraction depending on the corresponding scale introduced error. SIFT was an algorithm only using properties of gray ignoring color information.

The realization of SURF which based on function library of Opencv [18] was as Figure 5.

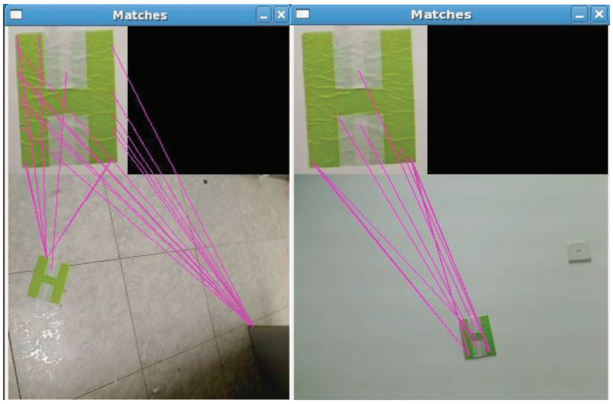

Figure 5: Realization of Target Tracking by SURF

The results as the Figure 5 told us that complicated environment might cause the target tracking error. As the left of the figure 5 when the feature points tracked based on SURF exceeded the region of target the position and velocity information was wrong. The wrong information of position and velocity might cause the UAV not to land on the helipad.

4.Improved Algorithm

According to the more computational requirements and target racking error we put forward a new calculation flow. Firstly we use Camshift to pretreat the image to detect the region of target. Secondly we use SURF to detect the feature points in the target region and the target helipad. We also use SURF to realize the feature points matching. This algorithm realizes the accurate target tracking. Computational requirements of Camshift are less than SURF, so the improved algorithm which is only used in the region of target reduce computational requirements. This algorithm can improve calculation efficiency of target identification and tracking. The comparison of computational requirements between Camshift and SURF is as table 1.

Table 1: Comparison of computational requirements between Camshift and SURF

	VIRT	RES	SHR	%CPU	%MEN	TIME+
SURF	75748	60m	5576	84.3	12.2	26.50
Camshift	21728	8960	5452	17.6	1.8	1.92

According to the above table we conclude that computational requirements of SURF is much more than Camshift in CPU occupied、memory profiler and the time of TIME+. Therefore before SURF detecting feature points we use Camshift to pretreat the frame of video to obtain the region of target. After getting the region of target we use SURF to detect feature points of the region of target not integrated image. We also use SURF to detect feature points of the template image and do the feature points matching between template image and target region image. This calculating idea can reduce computational requirements and be helpful to the real-time of control system on board. Not as [19~21] using white target and black background we use the template image as Figure 5.

In tracking process the pixel number of target is about 2.5% of the integrated image. With the ratio as the above told decreasing the calculation requirements also decrease. The comparison of computational requirements between Camshift&SURF and SURF is as table 2.

Table 2: Computational requirements of Camshift&SURF and SURF

	VIRT	RES	SHR	%CPU	%MEN	TIME+
SURF	21728	8960	5452	84.3	12.2	26.5
Camshift&SURF	34274	11m	5534	23.7	3.4	4.6

As table 2 we conclude that Camshift&SURF can reduce the computational requirements in deed.

5.Conclusion and Feature Work

In this paper the algorithm Camshift&SURF reduces the computational requirements. This algorithm is very useful for the UAV autonomous landing system. The algorithm not only can solve the problem of computational, but also can provide an accurate tracking system.

The most important work in the future is to use this algorithm in the UAV autonomous landing system.

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