Vision-Based Landing System Design for a Small UAV

[1]Yu-Fu Lin, [1]Wei-Min Lu, [1]Kuan-Hung Chen, and [2]Jiun-In Guo

[1]Department of Electronic Engineering, Feng-Chia University, Taiwan
[2]Department of Electronics Engineering, National Chiao-Tung University, Taiwan

***Abstract*-- This paper presents a vision-based landing system concept which could be implemented in a small UAV (Unmanned Aerial Vehicle). Vision-based object detection provides object position information of objects such as pedestrian or road, and those detection methods can also provide precise position during the landing stage of aircraft. Besides, the take off weight of a small UAV should be light in order to increase endurance. Vision-based sensor is much low-cost compared with other sensors such as RADAR (Radio Detection And Ranging), LiDAR (Light Detection And Ranging) or DGPS (differential GPS) module. However, vision-based object detection methods have several challenges such as weather conditions, low illumination capability, and high false detection rate in complicated environment. Accordingly, this paper presents a practical method that can conquers the above challenges for vision-based landing system for UAV. In addition to desktop simulation, we also realize the proposed method on a portable device.**

Keywords: Net-recovery, intelligent vision, object detection, vision-based landing, unmanned aerial vehicle.

I. INTRODUCTION

The small UAV with auto-pilot and camera modules is designed for commercial applications such as surveillance, traffic monitoring and forest conservation. However, the stage of aircraft landing is very dangerous. If system failure or human operation error such as turning in the wrong direction occurs, it might threaten personal safety of the crews. Consequently, autonomous net-recovery landing system could be a safer choice based on that the ground control station (GCS) of the UAV and external pilot (EP) are deployed in a safe place. The literature [1]–[2] has proposed method that efficiently utilizes rich camera information has enabled fully autonomous recovery of a small UAV.

There are several challenges for detecting recovery-net yet:

1. Propagation limitation: The literature has proposed a vision detection station on the ground receiving real-time video from vehicle. The delay time could reach as long as 200ms, and it could lead to large miss distance when UAV landing in high speed.
2. Weight limitation: In order to achieve system criterions of light, low-cost and low-power, the vision-detection board must be an embedded system environment that is poor in computation ability comparing with a desktop.
3. Reliability issue: The reliability of algorithm is a very important issue in aeronautic field. High detecting rate and high MTBF (mean time between failures) time is necessary. It takes long time to verify the reliability of the propose method.

Therefore, we tend to regard the vision-based landing system as a redundant system for a small UAV. We adopted vision-based landing system as main landing equipment until we gained the sufficient testing data, stable algorithm and reliable hardware.

The rest of this paper is organized as follows: Section II describes the literature review of vision-based object detection methods. In Section III we describe the proposed architecture to a small UAV. The experimental results and comparison are presented in Section IV. Finally, we give the conclusions in Section V.

II. LITERATURE REVIEW

In recent years, various types of vision-based methods for detecting or tracking objects have been proposed, which are also summarized as follows:

1. Image Difference model [3]

Using difference of continuous video frames can get results easily.

2. Camshift Method [4]

Camshift (Continuous Adaptive Mean Shift) method tracks objects with the feature of cylindrical-coordinate color space.

3. Kalman Filter [5]

The design [5] adopted physical motion model to calculate and predict the position and the velocity of objects to solve the obstacle problem.

4. Particle Filters [6]

Particle filters method uses stochastic model of edgewise particles to track moving objects.

5. Canny Edge Detection Method [7]

Canny operator uses a multi-stage algorithm to detect edge of object. The frame of net made in aluminum alloy that is significant objects could be detected by canny operator

III. THE PROPOSED RECOGNITION ARCHITECTURE IN A SMALL UAV

Vision-based machine learning algorithms are widely used in pattern recognition such as pedestrian detection, gesture learning and license plate recognition. However, vision-based methods sometimes get false alarms as patterns in the background similar to desired targets. On the other hand, UAV landing area is located in a wide territory. Unimportant objects could be enumerated such as grasslands, bushes, celestial space, sunset, and ground facilities. Hence, we can get proper parameters with enough training samples. To enhance the flexibility and stability of moving object detection, we propose the following architecture (shown in Fig.1).

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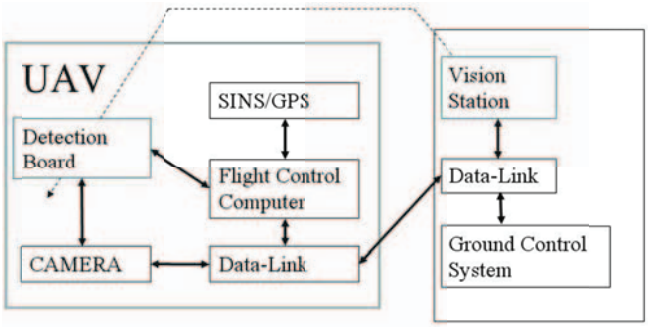

Fig. 1. Proposed Recognition Architecture

In Fig. 1, the "Detection Board" is an embedded system with a fast algorithm. Vision station on the ground monitors the recognition results and compares it with other algorithms. We can change parameter setting immediately by using auto mode or manual operation. This paper focus on the topic of on board detection.

IV. EXPERIMENTAL RESULTS AND COMPARISON

We used red net as target pattern. As shown in TABLE I, Camshift method is faster than the other methods when we trained test pattern by using a desktop computer (Intel Core i5-3470 CPU,Windows 8 64-bit version)with OpenCV toolkit installed. Besides, we also realized Camshift detection algorithm on a portable device named Pandaboard ES. The test results are shown in TABLE II. We got the average detection rate of 98.12% among total 13 testing video sequences. We established lookup table to overcome the problem of different illumination. Moreover, Fig 2 demonstrates some video snapshots of our detection results.

TABLE I
THE PERFORMANCE COMPARISON OF EXISTING OBJECT DETECTIONS

Methods	Canny	Histogram	Adaboost	Camshift
Results	29.7 fps	23 fps	38.5 fps	58.8 fps

TABLE II
THE CAMSHIFE ERFORMANCE COMPARISON OF DIFFERENT RESOLUTION VIDEO

Computing Devices	Video Resolution	OpenCV frame/s (fps)	C Code frame/s (fps)
PandaBoard ES/ (Desktop, intel i5)	1280x720	1.4/(15.3)	2.2/(30.3)
	720x480	5.0/(24.4)	6.3/(76.3)
	640x480	5.3/(38.5)	7.1/(90.9)
	360x240	12.8/(235.8)	20/(333.3)

V. CONCLUSION

Vision-based object detection method is an intelligence detection way similar to human behavior and is much low-cost/low-weight when compared with detection methods such as RADAR or LiDAR. However, vision-based object detection methods still have several drawbacks such as unstable detection rate and illumination sensitiveness which limit the usage in aeronautic applications. Accordingly, this paper presents a practical method for vision-based recovery net detection for UAV landing. From our experimental results, we found that the illumination and interference patterns are significant to the detection performance. In addition, a set of training videos is used in this paper. The detection performance of Camshift algorithm reaches 98.12% in the grassland.

Fig. 2. Several video snapshots of net recovery detection of the proposed design

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