A Robust Vision-based Method for Real-time Flight Parking Bays Monitoring

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Keywords: Parking Bays Monitoring; Vision-based Method; Flight Moving Tracking; Gaussian mixture model (GMM); Optical flow Method

Abstract: The arrival and departure time sampling of the flight is one of the key information for parking bays monitoring to avoid conflict. Nowadays the time is reported and recorded by hand in many airports, which fault and delay reports may happen. Safety risks and lower efficiency cannot be neglected. This paper presents a robust vision-based method to automatically sample the arrival and departure time on the bays by flight move tracking and keep the flight under intelligent surveillance with the camera in the ramp. Based on the Gaussian Mixture Model algorithm, the improved method provided successfully solves the light changing disturbance and other moving object influence with Optical Flow Methods, which has been applied in the eighty seven bays of Shanghai Hongqiao International Airport that is one of the major airports in China. The practical result shows that the accuracy rate is above 90% and the missed alarm rate below 1%.

Introduction

The airport ramp accidents are the one of the four civil aviation safety problems, which causes economic loss up to 10 billion dollars in the world. Among the accidents, the conditions in the area of parking bays are the worse, such as aircrafts rub, parking bays conflicts, and so on. Parking Bays monitoring and the arrival and departure time sample of flights on the bays by tracking are important for airports normal operation guarantee.

Fig.1. Airport parking bays

Nowadays, most airports depend on surface radar to surveillance [1], which has radar shadow especially in the parking bays area because of buildings and corridor bridges. So there is an interesting phenomena for the staff in the control center of airport to search flights with telescope, furthermore, the arrival and departure time of flights is sampled by the staff with radio, which affect the accuracy and efficiency of airport operation.

This paper provides a practical video surveillance method to improve the management level of flight parking bay monitoring by flight tracking based on the intelligent moving target analysis. The arrival and departure time is automatically sampled and provided to the airport berth allocation system. The key point is to real-time track the flight robustly with high accuracy and low false through intelligent video analysis sampled from the cameras equipped on the corridor bridge. The real-time accuracy rate below 90% and the false rate above 2% will not satisfy the airport operation requirements. However, there exists light change and other moving objects disturbance on the ramp, which affects the tracking accuracy.

In the following paper, four sections will be presented. In section 2, the related work on the flight tracking with several ways is introduced. Gaussian Mixture Model Method applied on the flight tracking is introduced in Section 3, which includes image pre-processing, foreground segmentation and the flight block tracking. The other moving objects and the light change cause false alarm during the tracking. In order to deal with such cases, two criterions are designed according to the appearance and the moving characters of the flight based on the optimal flow method to improve the robust in section 4. The practical result which is applied in Hongqiao Airport is demonstrated and the conclusion is finally achieved.

Related Work

There are some researches on flight tracking in these years, which can be classified into two ways except for surface radar surveillance. One is location tracking with Global Position System (GPS), the other way is carried out with video surveillance.

Tracking the flight with GPS is a traditional method, the GPS location information is transmitted by ADS-B system [1] from the flight to the ground control center. Like the situation of the surface radar, the GPS signal is often blocked or interfered around the parking bays by the terminals and the radio signal. On the other hand, sometimes the location error is about 10 meters for GPS, which doesn’t satisfied with application requirements.

With the development of computer vision technology, the flight tracking with Image and intelligent video analysis is researched. High-resolution satellite images using coarse-to-fine shape prior to detect aircraft is suggested [2].

Wavelet features, ANN and SVM classifier are proposed by [3] and [4], which hasn’t been used into practice because the methods are too complicated to achieve real-time requirements.

Flight Tracking with Gaussian Mixture Model Method

There are three common ways as mentioned in [5] to track moving objects, which are frame difference, optical flow and background subtraction. Frame difference can be implemented easily, but it has more limits than the other methods. Because of the complex environment in airport, the frame difference can’t guarantee the tracking accuracy. Although background subtraction algorithm is too complicated, it has better performance for extracting object information. Optical flow method as in [6] is robust but time consume. Since the pyramid and Lucas-Kanade algorithm combined in [7] are often used to improve the computing speed. AS a typical background subtraction method, Gaussian Mixture Model (GMM) is applied to the flight tracking firstly.

Image Pre-processing

Tracking the flight is to monitor the arrival time and departure time of the flight on the parking bay. To improve the tracking accuracy and real-time property, pre-processing is necessary. It includes three aspects:

Fig.2. detection area and direction line pre-set

Set detection area and direction line firstly. According to the berth's direction, polygon area is pre-set with more than 3 points and less than 10 points to surround aircraft parking berth. The direction line is also set (see in Fig.2.) consistent with direction of aircraft entered berth, which is used to judge the arrival or departure for the flight.

Secondly, bilinear interpolation is used to the images to normalize them into 352×288 pixels.

The third, converting RGB image into gray image to reduce the influence of lighting.

Foreground Segmentation and the Flight Block Tracking

GMM for multimodal background model is an effective method [8]. Modelling each pixel with GMM that being considered as one of the best models can describe the scene properly.

GMM functions are based on the probability density function of the Gaussians generated in the model [9]. The probability density function of single Gaussian is represented as follows:

$$f(x,\mu,\Sigma) = \frac{1}{(2\pi)^{\frac{3}{2}}\left|\Sigma\right|^{\frac{1}{2}}} e^{-\frac{1}{2}(x-\mu)^T \Sigma^{-1}(x-\mu)} \tag{1}$$

Where x is a random variable vector representing the pixels in three channels. μ is the mean vector of Gaussian distribution, $\sum$ is variance.

The intensity of each pixel is modelled:

$$P(x_t) = \sum_{i=1}^{N} \omega_{i,t} \times f(x_t, \mu_{i,t}, \sigma_{i,t}) \tag{2}$$

Where x_t is the pixel with a value of x_t at time t. $\omega_{i,t}$ is the weight of the i^{th} Gaussian in the mixture at time t. $\mu_{i,t}$ and $\sigma_{i,t}^2$ is the mean value and the variance of the i^{th} single Gaussian at time t. N generally depends on the specific size distribution of the pixel values. The greater N indicates the more peak, which means the greater ability to handle fluctuations. The range of N is generally between 3 and 5.

Whether the pixel matches the single Gaussian distribution or not is judged according to the formula (3).

$$\frac{(x_i - \mu_{i,t})^T (x_i - \mu_{i,t})}{\sigma_{i,t}^2} < \tau_\sigma^2 \tag{3}$$

Where τ_σ is the pre-set standard deviation.

If the current pixel satisfies the single Gaussian distribution, the weight of the corresponding single Gaussian distribution should be larger.

Update Gaussian mixture model:

$$\omega_{i,t} = (1-\alpha)\omega_{i,t-1} + \alpha M_{i,t} \tag{4}$$

α is learning rate that corresponding to the weight. $M_{i,t}$ is the single factor Gaussian distribution. If there is no matched model existed, $M_{i,t}$ is 0, otherwise, $M_{i,t}$ is 1.

When the new pixel value matches a single model, $\mu_{i,t}$ and $\sigma_{i,t}$ should be updated.

$$\begin{aligned} \mu_{i,t} &= (1-\rho)\mu_{i,t-1} + \rho x_t \\ \sigma_{i,t}^2 &= (1-\rho)\sigma_{i,t-1}^2 + \rho(x_t - \mu_{i,t})^2 \end{aligned} \tag{5}$$

ρ is the learning factor of single Gaussian distribution, its value is $\rho = \alpha / \omega_{i,t-1}$.

When the current pixel value can't be matched with any Gaussian mixture model, replace a current Gaussian mixture model whose weight is smallest with a new single model.

All the single Gaussian distribution models are reordered according to $f_{i,t}$ with descending order.

$$f_{i,t} = \omega_{i,t} / \sigma_{i,t} \tag{6}$$

Select n single Gaussian distribution model as the background of the scene:

$$B = \arg\min_n \left(\sum_{k=1}^{n} \omega_{i,k} > T\right) \tag{7}$$

T is the minimum threshold of the estimated background.

As described above, each pixel in the first frame image needs to be modelled and each single Gaussian distribution needs to be initialized. According the scene conditions of the parking bays monitoring, five parameters are initialized in table I below:

Table1. Gaussian mixture model parameters initialization

Parameter	Symbol	Value
Number of single Gaussian distribution	N	3
Multiple of the pre-set standard deviation	τ_{σ}	2.5
Minimum threshold of the estimated background	T	0.5
Initial weight	ω_{init}	0.02
Initial variance	σ_{init}^{2}	18

After foreground segmented, foreground image is extracted with morphological approach. The approach is erosion and dilation. Figure 3 shows the morphological processing results.

(a) The original images

(b) Morphological processing

Fig.3. The results after morphological processing

From the last image in figure 3, the foreground image extraction is affected by the moving persons and the vehicles.

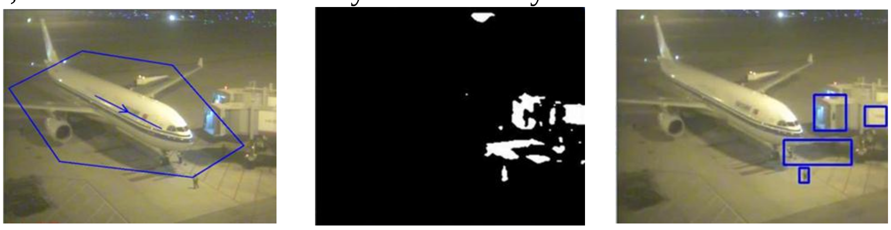
Flight Block Tracking

Tracking target block method is designed to separate the flight from other moving objects according to the external form of the flight. Circumscribed rectangles are extracted to form the target blocks. The boundary is determined by the maximum and minimum values of the abscissa and the ordinate of the target outline. Under the cases that the total number of pixels included in the target block is less than 50 or the length or width is less than 10 pixels, the target will be ignored.

When the first frame of the flight block is extracted, a unique number is given to the flight block. After extracting the target in next frame, the relationship between the flight block of the previous frame and the current frame is compute. If the rectangular area of overlap and the distance between the two centers satisfy certain conditions, the conclusion that they are the same target is achieved, otherwise they are different. If there are more than 10 different frames continuously, the flight target is judged to be missing and its information will not be concerned later. Figure 4 demonstrates the tracking results where the blue rectangles are the flight blocks.

Fig.4. The flight tracking result with the target block method

Normally, the tracking result is good with the GMM method and target block method. However, there are two cases affect the result (in figure 5.). One case is that the corridor bridge docked the flight moves, which often causes false alarm. The other case is that the light change on the parking bays, which affects the accuracy rate seriously.



(a) The impact of the moving corridor bridge

(b) The impact of light change

Fig.5. The two cases affecting the result

The reason for the first problem is that the GMM can only extract foreground rather than identify foreground. All the moving objects in the detection area will be segmented as foreground. At the same time, Gaussian mixture model method updates the central position of the current Gaussian distribution by comparing the current value of the pixel with Gaussian distribution center location, which only adapts to the slow changes of the light. When the light is too weak or too bright, the moving target would be recognized as background because the target's pixel values are similar to pixel values of background, which causes the flight detection failing.

Robust Improvement with Optimal Flow Method

To solve the other moving objects interfere and the light change affection, constraint rules are designed according to the flight moving pattern and appearance. The flight moving forward into the berth on straight line, which is usually different the moving direction of the corridor bridge and that of the other vehicles. On the other hand, the appearance of the flight is different from that of the other moving objects, which is the big and has typical shape. Even if the light is too weak or too bright and the flight is too similar with the background to be segmented, edges and features of the flight can be extracted obviously.

The optical flow method is adopted to take the advantages of the two constraint rules. Feature points are attracted by Harris corner points algorithm [10]. Pyramidal Lucas-Kanade algorithm is applied to match the corner points. To decrease the computation consumption, Feature points attraction and matching once every five images.

A direction line consistent with the direction of the flight arriving the berth is set. The angle between matched foreground points and the direction of the line is calculated using the vector dot product. Define two thresholds γ_1 and γ_2. If the flight arrives the berth, the angle should be less than the threshold γ_1. On the contrary, the angle should be larger than γ_2 while the flight departs the berth.

Another threshold of the number of matched feature points is given according to the flight appearance character, which means that the matched feature points are greater than that of other objects, such as trucks and humans.

Fig.6. Harris corner points extraction

With the obtained target block tracking and the matched feature points, that the flight arrives or departures is judged. If the target is moving into the berth, the target block will enter the detection area and some feature points will follow the target with some displacement. The displacement between each pair of matching feature points is calculated. If more than 0.1 pixels, the feature points are recognized as foreground points. Then the angle between matching foreground points and the direction of the line is calculated by using the vector dot product and compared with the two thresholds γ_1 and γ_2 to judge the direction. Furthermore, according to the number and moving pattern of foreground feature points, the other moving objects interference is decreased.

Application Results

After improvement with optimal flow method based on GMM method, the algorithm is applied on the parking area of Hongqiao International Airport to monitor the bays and sample the arrival time and the departure time of the flight.

The video is sampled with 25 fps and the image is 704×576. The flight tracking algorithm is run on the computer with Intel Core i3 CPU.

According to the practical environment conditions, two thresholds γ_1 and γ_2 are given: $\gamma_1 = 25^o, \gamma_2 = 155^o$.

Define the false alarm as the case that there is no flight to arrive or depart but alarm reported. And missed alarm is that there has flight arriving or leaving on the bay but no alarm reported.

Firstly, apply the robust improved algorithm with optimal flow method to monitor four bays for 24 hours. The video captured by four cameras on the bays. The result is compared with that of GMM algorithm as follows:

Table 2. Application results comparison

Detect result / algorithm	Record numbers	Actual numbers	False alarm	Missed alarm
Improved Algorithm	47	44	4	1
GMM algorithm	51	44	10	3

Furthermore, apply the improved algorithm on the eighty seven bays of Hongqiao Airport and the twenty days statistical result listed below.

Table 3. Practical application results comparison

Actual numbers	Alarm numbers	False Alarm	Missed alarm
444	469	28	3
394	419	29	4
387	410	26	3
440	457	20	3
434	462	31	3
391	418	30	3
393	406	16	3
359	386	29	2

341	359	19	1
351	376	27	2
322	339	18	1
400	434	34	0
316	342	27	1
313	338	27	2
394	401	10	3
409	436	31	4
322	337	15	0
351	371	22	2
348	369	23	2
403	416	16	3

The practical result shows that the accuracy rate for all the bays is above 90% and the missed alarm rate is below 1%, which satisfies the requirement and has been applied as one of important information to support airport operation in control center.

Conclusion

In this paper, the airport parking bays monitoring is implemented by intelligent video analysis method. The arrival and the departure moving of the flight are tracked based on the improved GMM algorithm. The improvement lies on two aspects. One is to identify the other moving objects from the flight on the parking bays. The other is to eliminate the disturbance of light change. Two criterions are designed and the GMM algorithm is improved with the optimal flow algorithm.

The experiment result is compared between the two algorithms before and after the improvement, which shows the two disturbance factors are limited. The improved algorithm is applied to the eighty seven bays monitoring of Hongqiao Airport and the statistical result in twenty days is achieved. The False alarm rate and the missed alarm rate are all satisfies the requirement of practical operation. The meaningful achievement of this paper is that it demonstrates the intelligent video analysis not only can be applied for safety surveillance, but also in the airport normal operation.

Acknowledgement

This work is financed by the NSF of China (Nos.61203186, 11372247). Great appreciate for the Control Centre of Shanghai Hongqiao International Airport. Without their helpful suggestions and supports, the practical value of this research can’t be achieved.

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