Airborne high-resolution image motion target detection combined with hyperspectral features

Wang Cailing¹ Zhang Yuchun² Guo Pu¹, Xu Jun²

¹ Xi’an Shiyou University, Xi’an, 710065, China
² Xi’an Aeronautical University, Xi’an, 710089, China

¹Corresponding author’s e-mail: 1018451102@qq.com

Abstract. Aiming at moving object detection in Airborne Hyperspectral Remote Sensing Images under complex background, this paper proposes a background removal method based on Mixture Gauss Model. Firstly, in order to eliminate the influence of the dithering of airborne platform on remote sensing image, this paper uses affine transform-based image registration algorithm to achieve the image registration of 3D data. Then, this paper selects specific spectral images, establishes the Mixture Gauss background model, and subtracts the background to achieve the extraction of moving objects. The experimental results show that the method can extract moving objects in Airborne Hyperspectral Remote Sensing Images effectively.

1. Introduction

The detection of moving objects is a hot topic in the fields of computer image processing, intelligent monitoring, recognition and tracking. It plays an important role in the field of computer interaction and human vision. It is of practical significance to study the detection of moving objects in airborne imaging. However, in the actual scene, there are many uncertainties or unpredictable states, such as shadows, illumination changes and camera jitter, which bring difficulties and obstacles to the detection of moving objects. Especially in the application system of visual navigation, the camera often moves with the carrier of UAV, UAV and so on. It needs to realize dynamic target tracking, and the problems of background change, shadow effect and camera jitter are very obvious. Therefore, how to estimate and compensate the motion of the camera to eliminate its interference to the moving target detection is particularly important.

There are many algorithms for moving object detection. Generally speaking, they can be divided into three categories: optical flow method, frame difference method and background subtraction method [1]. Optical flow method is complex in calculation and requires high hardware, so it is not suitable for the field with high real-time requirements. Inter-frame difference method has strong real-time performance, relatively simple implementation and good adaptability to dynamic environment, but it can not completely extract all the relevant points of the target. Background subtraction can get more complete targets, and the computational complexity of the algorithm is much lower than that of optical flow method, so the application of background subtraction is more extensive. Its basic principle is to establish background model based on the background of the pixel. By comparing the current image frame with the background model, we can determine the region where the colour of the pixel changes greatly, that is, the foreground region [2].
In this paper, an improved method of moving object detection in airborne imaging is proposed. The image registration algorithm based on affine transformation is used to realize the image registration of 3D data. Then the background subtraction method based on Mixed Gauss Model is used to enlarge the pixel difference between background and moving object by using the high resolution of hyperspectral data and the combination of atlas.

2. **Introduction of algorithms**

2.1. **Overview of Algorithms**

The basic idea of the algorithm is: firstly, the optimal band is selected from hyperspectral data set by band selection; then, the current frame image is registered with the previous frame image using affine transform image registration algorithm, and the global motion parameters are obtained and motion compensation is carried out; secondly, the compensated data set is used with mixed gaussian. Background subtraction is used to extract moving objects. The flow chart of the algorithm is shown in the figure.

2.2. **Band Selection of Hyperspectral Images**

Because of the complexity of background change, shadow effect and camera jitter in airborne imaging, there will be a certain false alarm rate when gray eigenvalue is used for detection. Hyperspectral data can detect the substances with diagnostic spectral absorption characteristics, and can accurately distinguish the types of vegetation cover on the surface and the materials on the road surface. However, because of its large amount of data and high redundancy, it is difficult to recognize hyperspectral images. Therefore, it is necessary to reduce the amount of data and save resources for dimensionality reduction. Two main methods of dimensionality reduction are feature extraction and band selection. Dimension reduction by feature extraction will change the physical meaning of original data. In contrast, band selection is a subset of bands that plays a major role in all bands of hyperspectral images. It can not only greatly reduce the data dimension of hyperspectral images, but also retain useful information more completely, and has special significance. In this paper, by calculating the information entropy of each band, we can select the bands with large information, small correlation and good class separability. The information entropy of band I in hyperspectral remote sensing image is expressed as follows:

\[
H(x_i) = -\sum_{i=0}^{n} P_j \log_2 P_j
\]

where \(P_j\) denotes the probability of spectral brightness value J in the band and n denotes the spectral brightness Series in the band.

2.3. **Image registration**

Aiming at the problems caused by illumination, aerial photography, noise and shooting angle in airborne imaging, in order to ensure the realization of target detection, it is necessary to register the original image acquired. Image registration is a measure of similarity between two or more images, and the background and illumination changes are corrected by affine transformation. In this paper, image registration technology based on affine transformation is used to realize 3D data image registration. SIFT is a local feature descriptor algorithm, which can detect key points in images. It keeps invariance to rotation, scale scaling, brightness change, and to a certain extent stability to view angle change, affine transformation and noise, and has scale invariance. The SIFT algorithm is used to extract the feature points of the image, and then the affine transformation formula is used to transform the feature points to obtain a stable registration image.

2.3.1. **Feature Extraction**

SIFT algorithm is used to extract the features of reference image and image to be registered. Firstly, the Gauss difference scale space is established, and the Gauss formula is used to calculate the
difference pyramid, and all the extreme points of the Gauss function are obtained[8]. Then eliminate the unreliable points and get the key points.

\[ L(x, y, \sigma) = G(x, y, \sigma) * I(x, y) \]

\[ D(x, y, \sigma) = [G(x, y, k\sigma) - G(x, y, \sigma)] * I(x, y) = L(x, y, k\sigma) - L(x, y, \sigma) \] (2)

When satisfied

\[ \frac{\text{Tr}(H)^2}{\text{Det}(H)} < \frac{(r+1)^2}{r} \] (3)

That is the key point, and vice versa.

2.3.2. Image registration

The required feature points are obtained and substituted into affine transformation relations for operation[9].

\[ \begin{bmatrix} x_B \\ y_B \end{bmatrix} = s \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & -\cos \theta \end{bmatrix} \begin{bmatrix} x_A \\ y_A \end{bmatrix} + \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix} \] (4)

Among them, \([x_B, y_B]\) is the coordinates of the feature points of the image to be registered, \([x_A, y_A]\) is the coordinates of the feature points of the reference image, \([\Delta x, \Delta y]\) is the translation of the coordinates, \(S\) is the scaling ratio of the image to be registered, and \(\theta\) is the rotation angle of the image to be registered relative to the reference image.

2.4. Target Detection

In this paper, the Gauss mixture model is used for target detection. After the background is extracted and updated, the moving object is extracted by background subtraction. Mixed Gauss Background Model (GMBM) is a background representation method based on the statistical information of pixel samples. The basic idea is to define \(K\) Gauss distributions for each pixel to describe the number of peaks of its multi-peak distribution to represent its state. The GMBM is used to model, and the model parameters are updated by iteration of pixels. In the process of measurement, as long as the pixel points conform to one of the \(K\) Gaussian distributions, then the point is considered as the background, and vice versa as the target. The probability density function of the \(K\) th Gauss distribution at time \(t\) is as follows:

\[ P(X_t) = \sum_{n=1}^{K} W_{n,t} * \eta(X_t, \mu_{n,t}, \Sigma_{n,t}) \] (5)

Formula \(\mu_{n,t}, \Sigma_{n,t}\) - Mean and Covariance Matrix, \(K\) is generally 3-5.

2.4.1. Background Selection

The \(K\)-gaussian distributions of each pixel are sorted from large to small according to the ratio of weights to standard deviations. The higher the probability of describing the background, the lower the probability of describing the background[11]. Therefore, the first \(B\) distributions are selected as background pixel models, as shown in formula. In the formula, \(H\) usually takes the best empirical threshold of 0.75.

\[ B = \arg \min (\sum_{n=1}^{B} W_{n,t}) > H \] (6)
2.4.2. Parameter update
For a new frame, the pixel value of the background image is compared with that of the existing I (i < K) Gauss model, if it satisfies:

\[ |X_t - \mu_{i,t-1}| \leq 2.5\sigma_{i,t-1} \]  

(7)

That means matching. The mean deviation is within 2.5. According to the formula, the parameters of Gauss distribution are updated, where \( \alpha \) is the learning rate and \( B\rho \) is the weight update rate.

\[ W_{n,t+1} = (1 + \alpha)W_{n,t} + \alpha \]  

(8)

\[ \rho = \frac{\alpha}{W_{n,t+1}} \]  

(9)

\[ \sigma^2_{n,t-1} = (1 - \rho) * \sigma^2_{n,t} + \rho * (X_{t+1} - \mu_{n,t+1}) \]  

(10)

\[ \mu_{n,t+1} = (1 - \rho) * \mu_{n,t} + \rho * X_{t+1} \]  

(11)

If the pixels of the current frame are not matched with K Gaussian distributions successfully, a new Gaussian distribution is used instead of the least weight Gaussian distribution. The new Gaussian distribution takes the current pixel value as the mean, and initializes a larger variance and a lower weight. The stable mixture Gaussian model is obtained by updating the parameters.

2.4.3. Target extraction
Comparing each pixel in the image with each Gaussian distribution of the Gaussian mixture model corresponding to the point, if the pixel value of the current frame does not match the B Gaussian model, the pixel is determined to be the foreground point, otherwise it is the background point.

3. Experiments

3.1. Data
The scenario used in this paper is part of a simulation of Rochester, New York, USA[12] [13]. Found the center in the target area and build an aerial imaging platform around it at the altitude of three kilometers. Using the adaptive imaging spectrometer, 61 aerial video with rectangular bands can be generated by moving at a uniform speed of 90 meters per second. The spatial resolution of the image is 0.3 m, the hyperspectral range is set to 400-1000 nm, and the hyperspectral resolution is high. The rate was 10 nm.

3.2. Experiments
This experiment is implemented in the environment of MATLAB 2016a. Select a group of scenarios for experiment, select the bands with large amount of hyperspectral information, small correlation and good class separability. After calculating and selecting 31 bands, the image is registered on the basis of the previous frame image, and the data set after registration is obtained. Then the new data set is processed by using the Mixture Gauss Background Subtraction Model. Detection of moving objects.

3.2.1. Image registration experiment
In this project, image_1 data is selected as the reference data to achieve image calibration of image_2 data; image_2 data after calibration is selected and marked as image_2_corrected as the reference data, image_3 data is calibrated, and then 10 groups of data are calibrated by analogy.

3.2.2. Target Detection Experiment
The new data set is detected by using the Mixture Gauss Background Subtraction Model. The first frame is read into the background frame. The number of model sets is 3. The deviation threshold is 2.5, the foreground threshold is 0.20, the initial standard deviation is 10, the model is updated and matched. If the pixel difference is less than the threshold, the point belongs to the background. Otherwise, it will
be the future. In the detection results, the moving target is set in white area and the background is set in black area.

3.3. Analysis of experimental results

Some experimental results are compared as shown in the figure.

![Figure 1. Image_2 Comparison of experimental results](image)

![Figure 2. Image_3 Comparison of experimental results](image)
From the experimental results, there are many interference factors in the target detection results of the original image, and many pixels in the background area are also detected as moving objects, and the detected target area is not complete. In the corrected target detection results, the background of the image passes through geometric rotation due to the geometric registration of the image. The rotation and translation are basically consistent, the interference factors in the background are well overcome, the detection of moving objects is more complete, and the effectiveness of the detection results is obviously better than the original image. Generally speaking, the detection of this algorithm can realize the moving target detection of airborne imaging.

4. Summary
Aiming at the fact that traditional moving object detection methods can not detect and track airborne moving objects accurately and in real time, this paper proposes a moving object detection and tracking method based on Gauss mixture model. Firstly, the largest band of hyperspectral image information is selected and preprocessed by image geometric registration. Moving targets are detected by background subtraction of Mixture Gauss Background Model. The experimental results show that after image registration of airborne imaging data, moving targets in dynamic background can be effectively extracted by using the detection method of Mixture Gauss Background Model. However, there are still some problems in this paper: the detection results of moving targets are not clear enough, and there are some deviations. In future research, it is necessary to further improve the contour extraction.

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