IMAGE REGISTRATION AND TARGET TRACKING

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Abstract

Automatic detection and tracking of interesting targets from a sequence of images obtained from a reconnaissance platform is an interesting area of research for defense related application. Image registration is the basic step used in tracking application. The paper describes a brief review of some of the image registration algorithms, analyze their performance using a suitable image processing hardware and selects the most suitable algorithm for a real time tracking application. The paper uses cubic spline model and a Kalman filter model for prediction of occluded target. The algorithms developed are implemented in a Ground based Image Exploitation System (GIES) developed at ADE for UAV application and results presented for the images obtained during actual flight trial.
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Keywords: Unmanned Aerial Vehicle(UAV), image registration, mis-registration, real time target tracking, target occlusion,, cubic-spline model, Kalman filter,

1. Introduction

A study on real time tracking of targets from a sequence of imagery primarily consists of two major tasks

(1) Analysis of image registration algorithms
(2) Applying registration algorithm for tracking application

In the present scenario, the video images are obtained from an aircraft, which is a Unmanned Aerial Vehicle (UAV) with on-board guidance and navigation system. The aircraft carries a camera in a gimbal which acquires images of the territory and sends the information to a Ground Control Station (GCS) in real time. During flight, the pilot in the Ground Control Station may identify a region of interest with a mouse click on the real time video where a target is present. The target which appears on a small window, could be tracked by engaging track mode. The position of the target at all subsequent frames are identified by the window and the information is transmitted to the onboard gyro stabilization platform (platform on which the camera is mounted) to correct the azimuth and elevation of the camera so that the target appears at the center of the frame throughout tracking.

The objective of the present work are the following:

- To study existing image registration algorithms, analyze their computation time, find the accuracy of match points and probability of obtaining false match points
- Applying registration algorithm for a real time imaging application of target tracking
- Development of prediction algorithm for occluded target

2. Image Registration

Image Registration is a process, which finds the location where optimal matching is obtained by matching a template image called the reference image over the searching region of an input image using a. suitable similarity measures. The method although computationally intensive, is simple, straightforward and robust and requires no apriori information about the two images.

2.1 Search strategy

The two conflicting requirements of image registration are the time and accuracy. Accordingly, one can employ a fine search (brute force) or a coarse-fine search (efficient in time) method. In fine search strategy, registration starts at the top left corner of the search space and continues along each row and column moving the sub image by one pixel each time. The accuracy of registration algorithm using fine search is good but the computation time is large. In coarse-fine search strategy, registration is done by extracting sub images of equal size as that of the reference image at the start of search space on a coarse grid at every m^{th} point. An approximate match point is found at the end of this step. A full search is done in a local region surrounding this match point. A coarse-fine search strategy is efficient if the system allows a minor degradation in accuracy. In order to decide algorithms suitable for real time tracking application, selection of appropriate algorithm is very important.

2.2 Algorithms

A number of image registration algorithms [1-6] are studied on images with varying size of search space and reference image. All these algorithms are based on similarity measure between the reference image and search space. The key issues in image registration are the time required for registration and the accuracy of registration viz., measure of how close is the match between sub image in the search space and the reference image.

2.2.1 Histogram based approaches

The basic principle underlying this approach is to compare the gray level histogram of the reference image to the sub image in the search space. Registration using these methods are less accurate, and may give rise to false matches.

(i) Normalized histogram intersection method

In this method, the sum of minimum gray level counts for each of k gray levels normalized with respect to the reference histogram gray level result in the match value of k. The best match value is calculated using the following formula:

$$\sum_{i=1}^{k} \frac{\min(Rhist[i], Chist[i])}{Rhist[i]}$$

where *Rhist[i]* is the histogram of the reference image and *Chist[i]* is the histogram of the sub image.

(ii) Correlation of histograms

In this method the correlation between the histogram of the reference image and the histogram of sub image in the search space is evaluated. The correlation coefficient value ranges from 0 (for no match) to 1 (for perfect match).

2.2.2 Normalized area correlation

A classical technique for registering a pair of functions is to form a correlation measure between functions and determine the location of the maximum correlation. A common criticism of the correlation measure form of image registration is the large amount of computation that must be performed if the window and the search regions are large. With this technique, no decision can be made until the entire correlation coefficient values are calculated.

2.2.3 Statistical properties based approach

In this method, the statistical properties of the image viz., brightness, contrast, entropy and moments are taken as measure for comparison. This method can be used in stand-alone mode or in conjunction with any of the other methods. The statistical properties for the reference and sub image in the search space is calculated and compared. The ratio of standard deviation to the mean (σ_x / m_x) represents coefficient of variation and is used for comparison.

2.2.4 Sequential Similarity Detection Algorithm (SSDA)

In this method, the absolute sum of differences between corresponding pixels in the reference image and the sub image in the search space is used as the measure of registration. When registration is perfect, the sum of residual differences has a minimum value but increases rapidly when there is no match.

If (x_1, y_1) is the true match point in the search space and registration algorithm shows a match point at (x_2, y_2), the distance $|(x_2 - x_1) + (y_2 - y_1)|$ is given a threshold. Two different SSDA algorithms are: constant threshold SSDA and automatic threshold SSDA. In constant threshold SSDA, the sum of residual differences between a best match sub image and the reference image is known apriori and slightly larger value than the sum of residual differences is used as threshold T. In automatic threshold SSDA, the addition is first done to completion without threshold value and the resultant sum of residual difference is used as the first threshold value.

2.3 Analysis

Analysis of computation time, accuracy of registration, calculation of mis registration and effect of reference window size on mis registration is done for a number of sample images. In all cases size of the reference image is taken as (50x50) whereas the size of the search space is taken as (100x100).

2.3.1 Computation time

The analysis of computation time for the registration algorithms described above has been carried out for some sample images. It is seen from the timing analysis shown in Table 1(a), that the coarse-fine search strategy using SSDA with automatic threshold has the best performance.

2.3.2 Accuracy of registration

Accuracy of registration is usually calculated using the following formula:

$$\frac{\sum_{i=1}^{l}\sum_{j=1}^{m}(R(i,j)-S(i,j)}{lm}$$

where R(i,j) is the reference image and S(i,j)is the matched sub image in the search space l x m.

Matching is termed as mis registration, if the sum of residual differences at the best match point exceeds the specified threshold. Table 1(b) shows the error in matching location using different methods of registration.

2.3.3 Effect of window size on mis registration

In order to study the size of reference window on the accuracy of registration, SSDA and area correlation algorithms are run with varying size of the reference window in the search space. Typical results in Table 1(c) show that the ambiguity in registration starts increasing with the reduction in the size of the reference window in the search space. The ambiguity is due to the fact that multiple number of points in the search space attains the same match value. From these multiple number of points, if the farthest point is at a distance greater than a specified threshold, the match point is termed as mis registration. Mis registration starts sooner in SSDA.

3. Real time target tracking [7-10]

3.1 Issues

Following are the main issues of real time target tracking:

(i) Computational complexity of the algorithms; Algorithm employed for tracking should be efficient in time.

(ii) Hardware processing of the real time tracking algorithms; Real time image processing is done on a Pentium PC with a real time acquire board and a Computation Module Controller (CMC), where specific image processing routines are implemented in hardware using library calls available in the system [11].

(iii) Adaptive tracking; If the target in the search space varies greatly in size, shape or orientation from the reference image, no true match can be found and the target in search space may fade into background noise.

(iv) *Walk-off errors during tracking;* If the reference image do not exactly match the target in the search space, the point where the template best matches the target would not correspond to the center of the target. This produces an error in match value and may accumulate to such a point that it "walks off" from the target.

(v)Tracking maintainability in presence of small interval occlusions; Target may be partially or fully occluded for some time during tracking. Hence suitable prediction algorithm should be developed which would be able to predict a target position in some later time interval based on the current trajectory.

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3.2 Target occlusion

Occlusion of a target while tracking may occur through natural or man made objects in the scene coming into the line of sight of the target or through deliberate deployment of counter measures such as smoke. The method of overcoming occlusions is to predict the movement of target using a track memory containing the history of the previous locations of the target.

In this paper two methods of prediction of target occlusion is discussed.

3.2.1 Cubic Spline model

The first method is based on approximation of the target trajectory using a cubic Spline model [12]. The observations in the current scenario are X and Y location of the target in subsequent frames with respect to time. In order to calculate the predicted position (X, Y) of the target at any instant, the cubic spline model has to be applied twice, once for prediction 'X' with (X, t) as input and second time for prediction of 'Y' with (Y, t) as input. As soon as tracking starts, the (X, Y) displacement of the target in every frame is stored in a queue so that at the point of occlusion, the queue has the latest 'n' number of values of (X, Y). Cubic spline prediction is now applied to (X, t) and (Y, t) to get the predicted position of (Xn+1, t) and (Yn+1, t) for the next frame. The newly computed (X, Y) is added to the queue and the prediction is repeated for the next frame. At any instant of time, if the target reappears at the predicted position (determined by searching in the area around the predicted position), the tracking continues and the system locks on to the target.

If the target has an oscillatory motion either in the 'X' or in the 'Y' direction, the cubic spline need to be smoothed. Study has shown that using smoothing and a reduced time step in the computation, the predicted target position during occlusion almost follows the actual observations.

3.3.2 Spline -model Kalman Filter (SKF)

The second method, is a Spline model Kalman Filter (SKF)[13]. The filter operates in a 'predictor-corrector' fashion and assumes that the target trajectory can be adequately approximated by a continuous curve, which is twice differentiable. A cubic polynomial satisfies the differentiable property. However no single cubic polynomial is sufficient to represent a target trajectory in the current scenario of UAV tracking. By the application of spline functions, a trajectory can be represented by a cubic polynomial over each of the various time intervals of the trajectory. Physically, an aircraft derives its maneuverability from various maneuvering forces, e.g., thrust, lift, and drag, which cause changes in acceleration. Rate of change in acceleration is assumed to be constant during a specific time interval. Clearly by specifying the third derivative and duration of time interval, a target trajectory can be approximated to any desired accuracy.

4. Results and discussion

Fig 1 shows the result of real time target tracking using modified SSDA method. The target under track is enclosed in a track window of (40x40) pixels and the algorithm employs a coarse-fine search strategy (coarse search with step size of 3 pixels) for tracking. To demonstrate the working of cubic spline model, a video sequence is created where a specific target after blanking for a period of 3 seconds reappears again. The results for 11 frames of successive time instant are shown in Fig 2. Frame 1 to 4 shows the target position while tracking. At frame 4, the target is lost and prediction starts. Frames 5 to 9 show the predicted position of the target using cubic spline model. Target reappears in frame 10 and tracking resumes as shown in frame 10 and 11.

The model of the Kalman filter has been applied to the target trajectory (observations obtained by target tracking using SSDA) and simulated using MATLAB tool to ascertain the performance of this model. The initial noise has been assumed to be white noise. It is seen from the study that the error is more in the initial phase of prediction as enough observations are not available. But this error (innovation) settles down with time and the model continuously tunes itself iteratively for better predictions. After passage of some time, (the point where the innovations settle down), the predicted output of the model matches very closely to the true observations.

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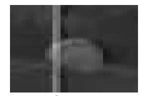
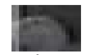
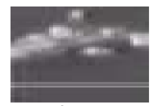
(a)

Sl.no.	Images	Algorithm	Time for fine search in seconds	Time for coarse-fine search in seconds
1.	 Search space (100 x 100)  Ref image (50x50)	Histogram Intersection method	18.361000	2.142
2.		Cross Correlation of histogram	24.321000	2.665
3.		Statistical properties based	10.20000	1.2143
4.		Constant threshold SSDA (SSDA1)	5.358000	0.6046
5.		Automatic threshold SSDA (SSDA 2)	4.306000	0.4791
6.		Area Correlation method	36.823000	4.1487
1.	 Search space (80 x 80)  Ref image (40x40)	Histogram Intersection method	7.4412	0.8324
2.		Cross Correlation of histogram	9.9272	1.212
3.		Statistical properties based	4.145	0.459
4.		Constant threshold SSDA (SSDA1)	2.172	0.2419
5.		Automatic threshold SSDA (SSDA 2)	1.7451	0.2017
6.		Area Correlation method	14.932	1.7232

(b)

Images	Algorithm	Error in matching location
 Search space  Ref image	Normalized histogram Intersection method	19.104
	Cross Correlation of histogram	18.214
	Statistical properties based	21.8908
	Automatic threshold SSDA	10.816
	Area Correlation method	10.816

Images	Algorithm	Error in matching location
 Search space  Ref image	Normalized histogram Intersection method	23.632
	Cross Correlation of histogram	18.348
	Statistical properties based	17.6080
	Automatic threshold SSDA	17.60800
	Area Correlation method	17.60800

Images	Algorithm	Error in matching location
 Search space  Ref image	Normalized histogram Intersection method	13.60900
	Cross Correlation of histogram	11.36120
	Statistical properties based	12.81800
	Automatic threshold SSDA	8.9812
	Area Correlation method	8.9812

(c)

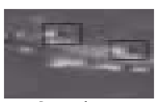
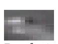
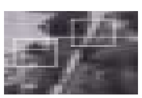
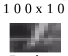
Images	Size of the reference image	Algorithm	Error in matching	Accuracy
 Search space (100x100)  Ref. image (20x20)	70 x 70	Automatic threshold SSDA	29.1893	Correct match
		Area Correlation method	29.1893	Correct match
	50 x50	Automatic threshold SSDA	28.4789	Correct match
		Area Correlation method	28.4789	Correct match
	40 x 40	Automatic threshold SSDA	21.419374	Correct match
		Area Correlation method	21.419374	Correct match
	30 x 30	Automatic threshold SSDA	17.705	Correct match
		Area Correlation method	17.705	Correct match
	20 x 20	Automatic threshold SSDA	14.975	Mis match
		Area Correlation method	14.975	TRUE
 Search space (100x100)  Ref image (20x20)	70 x 70	Automatic threshold SSDA	18.723	Correct match
		Area Correlation method	18.723	Correct match
	50 x50	Automatic threshold SSDA	17.342	Correct match
		Area Correlation method	17.342	Correct match
	40 x 40	Automatic threshold SSDA	12.321	Correct match
		Area Correlation method	10.787	Correct match
	30 x 30	Automatic threshold SSDA	12.321	Mis match
		Area Correlation method	10.787	Correct match
	20 x 20	Automatic threshold SSDA	5.257	Mis match
		Area Correlation method	5.257	Mis match

Table 1(a) Execution time of various image registration algorithms

(b) Error analysis between reference image and the search space

(c) Effect of window size on the accuracy of registration

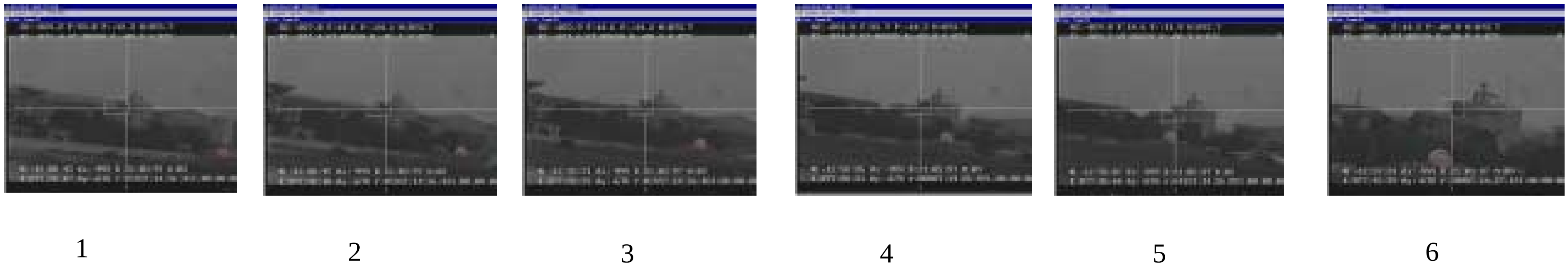


Fig 1 Tracking using SSDA method (red window shows the enclosed target). The time 14:26:41 represents the starting time in Frame 1. The tracking sequence is from Frame 1 to 6

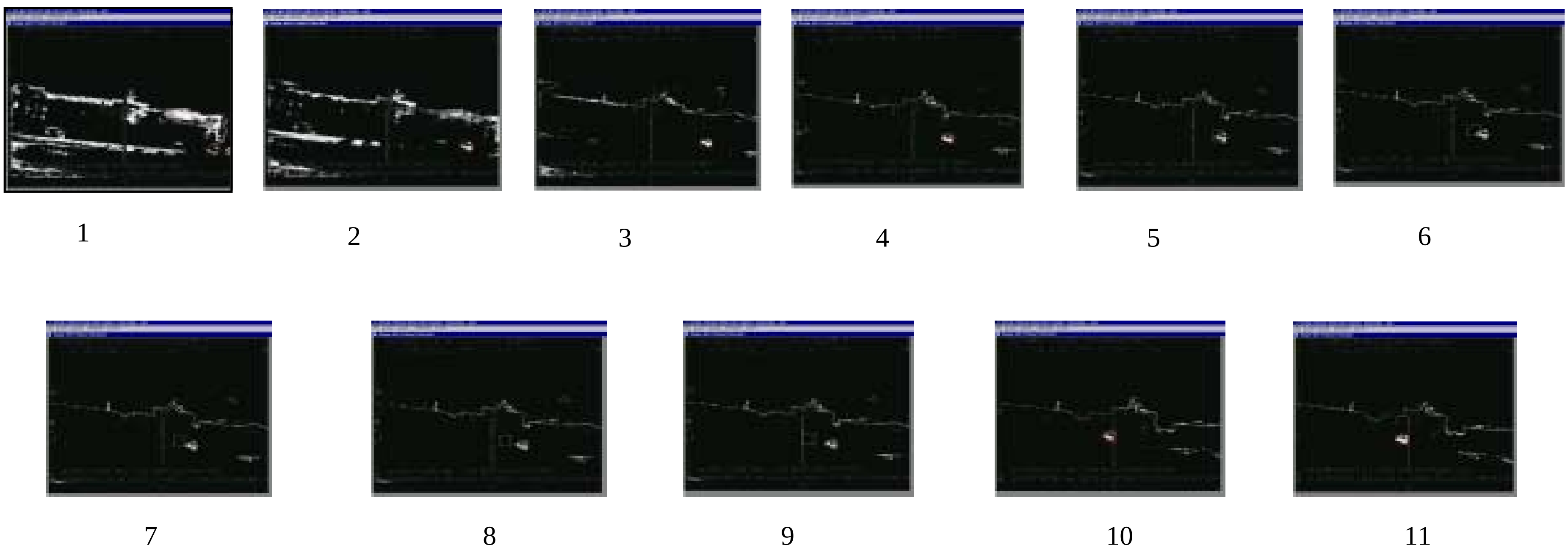


Fig.2 Tracking during obscuration using cubic spline approach. The tracking sequence is from frame 1 to frame 11