실시간 영상 지오레퍼런싱을 위한 KLT 트랙커의 속도개선
Speeding up the KLT Tracker for Realtime Image Georeferencing

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Abstract

The demand for human security significantly promotes the development of surveillance applications using a multi-sensor integrated UAV system. For more sophisticated operations, the system should provide a sequence of images rectified in a ground coordinate system in realtime. This rectification requires accurate position and attitude of the camera at the time of exposure of each image, which can be estimated through an Aerial Triangulation process using the GPS/INS data and tie points between adjacent images. In this work, the KLT tracker is utilized to obtain the tie points. To satisfy the realtime requirements, we present an approach to speed up the tracker by supplying the initial guessed positions of tie points based on the exterior orientation. The experimental results show that, when the guessed positions are supplied, the KLT tracker consumed less computational time than the ordinary KLT which is more suitable to be incorporated into the realtime image georeferencing process.

▸ Keywords : KLT Algorithm, Feature Tracker, Image Georeferencing, Exterior Orientation

1. Introduction

The growing requirement to improve human security leads to the increasing demand for surveillance applications. With a suite of sensors on a UAV platform, such a system can provide sequences of images over target areas. These images are, however, acquired at individually different locations and attitudes which partially overlapped. For more sophisticated operations, the system should rather provide the image sequences that have been rectified in a ground coordinate system in realtime. This rectification requires accurate position and attitude of the camera at the time of exposure of each image, which can be estimated through an Aerial Triangulation process using the GPS/INS data and tie points between adjacent images (Schenk, 1999). In this work, we utilized the KLT tracker to obtain those set of tie points. To beat the realtime image georeferencing requirement, the KLT tracker must be speeded up to obtain the tie points with minimal amount of computational time.

2. KLT and the Speeding up Methodology

The KLT is one of the known feature tracking techniques which has been widely used due to its effectiveness in selecting good features and how to track them (Bradski and Kaehler, 2008; Shi and Tomasi, 1994). As discussed by Bouguet (2000), once a set of good features in the first image are identified, their tie point in the adjacent image is determined by iteratively deriving an optical flow vector $d = [d_x\ d_y]^T$, for each point, that minimizes the residual function ϵ between the first image A and the subsequent image B.

$$\varepsilon(d) = \varepsilon(d_x, d_y) = \sum_{x=p_x-w_x}^{p_x+w_x} \sum_{y=p_y-w_y}^{p_y+w_y} (A(x,y) - B(x+d_x, y+d_y))^2 \quad (1)$$

where (p_x, p_y) and (w_x, w_y) denote the position of an image point and the dimension of the window patch, respectively. This tracking process is usually implemented based on pyramidal scheme to be able to handle large and noncoherent motions between image frames. When the displacements between two image frames are large, the KLT tracking process will definitely require a large number of iterations to converge to the final solution and consume a large amount of execution time.

A simple but efficient approach to reduce the computational time for the tracking process is to provide initial tracking positions that are close to the corresponding tie points. In this work, we proposed to supply the KLT tracker with the initial guessed positions using the exterior orientation method. With the location of the perspective center (PC) and the orientation of the camera (ω, ϕ, κ) suggested by the GPS and INS, we can determine the approximated positions of the corresponding points using the collinearity equation with the assumption that the terrain is a virtual horizontal plane with the average elevation. Depending on the accuracy of the exterior orientation parameters, the initial guessed position can be very close to the actual tie points which can make the tracking process to run at a small number of iterations with a few pyramidal depth levels. Finally the computational time will be decrease.

3. Experiment and Result Analysis

In this experiment, we aimed to measure the accuracy and computational time of the ordinary KLT tracker and the one which has been supplied with initial guessed positions. A pair of consecutive aerial images presented as Figure 1 was used as the inputs. We started our experiment by using the KLT tracker to extract a set of good features to track from the first image. With the exterior orientation parameters, we calculated the corresponding points in the second image using the collinearity equation. To evaluate how close the initial positions are, we manually extracted the set of tie points from the second image and present the distances as shown in Table 1.

First Image　　Second Image

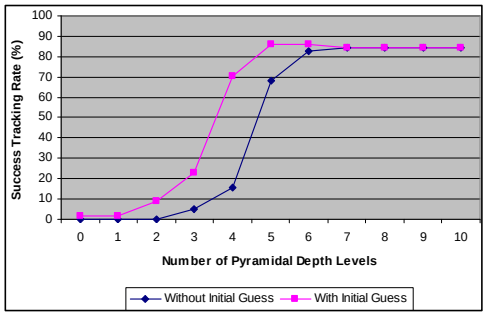
[Figure 1] A pair of consecutive aerial images used in the experiment

[Table 1] Displacements between a pair of consecutive aerial images.

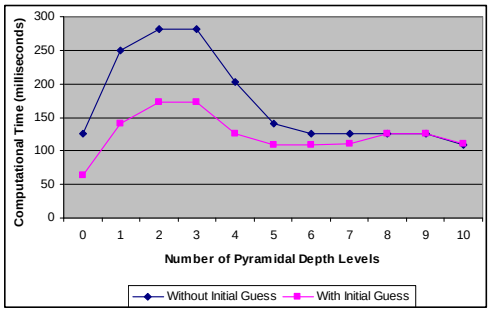
Condition	Displacements between the good features in the 1st image to its matched point in the 2nd image		Displacements between the initial guessed positions in the 1st image to its matched point in the 2nd image	
Parameter	Average	Maximum	Average	Maximum
x	527.4	605.1	39.2	70.7
y	105.6	171.7	141.1	197.7

Originally, the distances between the first image and the second image are quite large especially the x-coordinate in which its maximum distance is 605 pixels. The initial guessed positions obtained from exterior orientation can reduce the distances in the x axis while the distances in the y axis are increased. However, comparing in overall, the displacements between the initial guessed positions and its corresponding point in the second image are smaller.

As illustrated in Figure 2(a), without initial guessed positions for the tie points, the KLT tracker can achieve its maximum tracking rate at 84.21% when using 7 pyramidal depth levels. With initial guessed, the KLT tracker can achieve the equivalent tracking rate when using only 5 pyramidal levels. Figure 2(b) shows that, at this tracking rate and without initial guesses, the KLT tracker consumes 125 milliseconds while, with initial guesses, the execution time is moderately reduced to 109 milliseconds. The results demonstrates our valid assumption that supplying the KLT tracker with the initial guessed for the tie points can accelerate the tracking execution time. The speed improvement, however, is not significant. This is due to the low accurate GPS/INS data we obtained that result in the initial guessed positions to be not close enough to the actual positions.



(a) Measurement of success tracking rate



(b) Measurement of computational time

[Figure 2] Comparison of the KLT tracking measurements with and without guesses

4. Discussion and Concluding Remarks

In this paper, we present an efficient but simple approach to speed up the KLT tracker. The computational time of the KLT tracking process is decrease when there are initial guessed positions for the tie points, that are sufficiently closed to the actual positions, supplied to the tracker since the process can start its tracking function from that hinted positions instead. In this work, we proposed to supply the KLT tracker with the initial guessed positions based on the exterior orientation method. The experimental results show that, when the initial guessed positions are supplied, the KLT tracker consumed less computational time at the same accuracy as the ordinary KLT tracker. Therefore, this speeded up KLT tracker will definitely be more suitable to incorporate into the realtime image georeferencing process that appreciates small execution time to satisfy the realtime requirement.

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