TRIPLET IMAGE MATCHING FOR AIRBORNE DIGITAL SENSOR ADS40

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ABSTRACT:

3D reconstruction from multiple images is one of the most attractive and challenging research fields in photogrammetry and computer vision. One of the practical applications of 3D reconstruction techniques is automated generation of Digital Surface Models (DSMs) from satellite or airborne images. However, it is not easy to obtain a reliable DSM through image matching mainly due to the complexity of urban environments and lack of adequate information for accurate matching. A recently developed commercial Airborne Digital Sensor ADS40 can provide plentiful information and detailed description of complex urban features. Thus, there is a great demand for development of corresponding new strategies to exploit the abundant information and special characteristics of the new sensor. This study introduces a hierarchical triplet image matching strategy for ADS40.

1. INTRODUCTION

DSMs/DTMs are required for topographic mapping, spatial data visualisation, ortho-image production and many other engineering and environmental applications. Automated DSM generation through correlation-based stereo is still a challenging field due to the complexity of urban environments. The efforts to acquire reliable DSMs often suffer with a lot of problems such as occlusions, height discontinuities, repetitive patterns and ambiguous textures.

An effective way to increase the performance of image matching is to increase the number of stereoscopic measurements, which relies on a large amount of data in order to achieve a high redundancy (Nonin, P., 2003). Handling such large amount of data can be cost effective if the whole process is highly automated, however this can hardly be realized using traditional aerial photography.

Recently, a number of airborne digital CCD line sensors have been developed, including ADS40, TLS, DPA and HRSC. These digital push-broom sensors can provide plentiful information and detailed description of complex urban features and greatly enhance the efficiency of a photogrammetric processing. Thus, there is a great demand for development of corresponding strategies to exploit the abundant information and special characteristics of CCD line sensors, and subsequently improve the matching performance.

In this study, a hierarchical coarse-to-fine matching strategy is proposed for airborne digital sensor ADS40. An algorithm for feature-based matching over multiple views leads to substantial reduction of problems caused by occlusions through the intersection of more than two image rays. Adequate utilization of ADS40 data, which has a wide radiometric range and a good signal to noise ratio, improves the ability of reducing the ambiguity at matching level. Also, the precise exterior orientation acquired from GPS/INS system enables to perform a geometric constrained matching and speed up the searching process.

2. AIRBORNE DIGITAL SENSOR ADS40

The Airborne Digital Sensor ADS40 is the first commercial airborne push-broom camera developed by Leica Geosystems. It incorporates latest GPS and INS technology for sensor orientation and new developments in sensor technology, and allows precise photogrammetric processing and multispectral image analysis and interpretation.

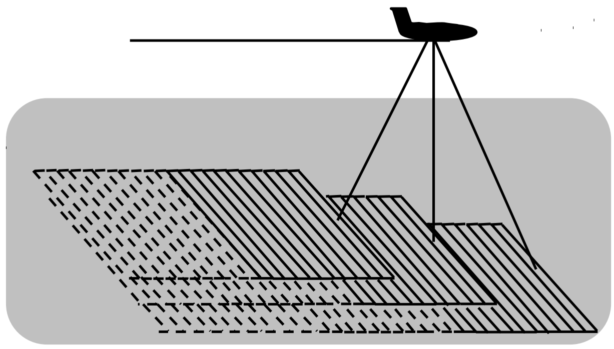

Figure 1. Three-line scanner

The ADS40 sensor exploits a three-line-scanner principle. Long linear CCD arrays on the focal plane capture panchromatic images looking forward, nadir and backward from the aircraft (Figure 1). Besides, four CCD lines for multispectral bands (RGB and NIR) can provide high-resolution data both for achieving the redundancy for photogrammetric processing and multispectral image analysis. Figure 2 shows different viewing angles of panchromatic and multispectral images. A specially designed Position and Orientation System (POS) from Applanix Corporation collects data about the aircraft's trajectory to ensure a successful ground processing, and meets the goals of high image quality. Each panchromatic channel consists of two lines, each with 12000 pixels, staggered by 0.5 pixel, usually one staggered line for each panchromatic channel is used.

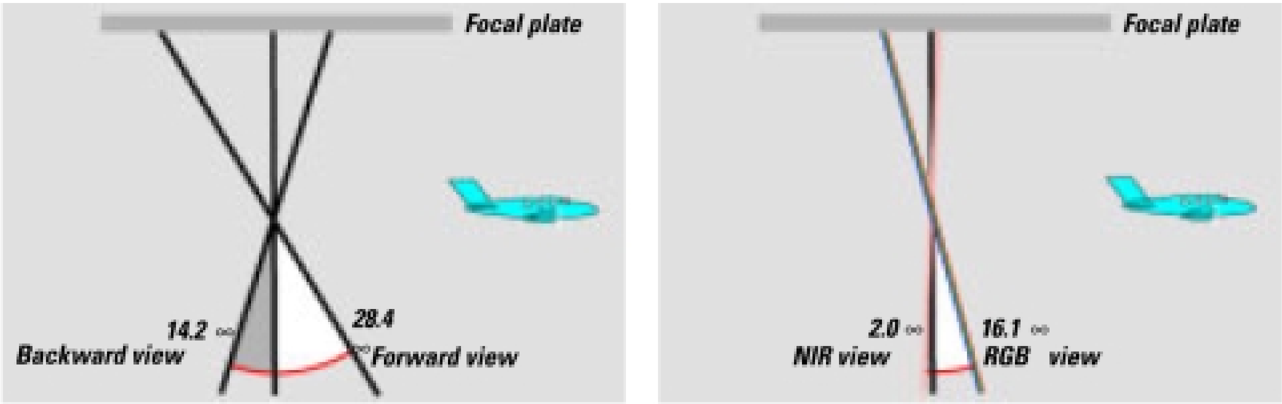

Figure 2. Different viewing angles of ADS40 panchromatic and multi-spectral images

All the panchromatic and multi-spectral data have a high radiometric resolution and provide a good signal-to-noise ratio. The characteristics of the ADS40 sensor are shown in Table 1. A more detailed discussion of the characteristics of ADS40 sensor can be found in Reulke et al. (2000), Sandau et al. (2000) and Tempelmann et al. (2000).

The ADS40 sensor captures imagery seamlessly along the flown strip, i.e. 100% of the ground surface is scanned in several strips quasi-simultaneously, which has great advantages in both geometry and image matching procedures, and far superior to that in typical aerial photography. This greatly facilitates the subsequent photogrammetric processing such as rectification, automatic point matching, block adjustment, DEM generation and orthophoto generation.

Focal length	62.77mm
Pixel size	6.5 μm x 6.5 μm
Field of view across flight line	64°
Pixels per CCD line (PAN)	2 x 12000
Pixels per CCD line (RGB and NIR)	12000
Dynamic range	14 bits
Stereo angle (forward – nadir)	28.4°
Stereo angle (nadir – backward)	14.2°
Stereo angle (nadir – NIR)	2.0°
Stereo angle (RGB – nadir)	16.1°

Table 1. Sensor characteristics of ADS40

3. MATCHING STRATEGY

The ADS40 sensor is able to acquire digital data with high geometric and radiometric resolution. All ground objects are recorded in three panchromatic and four multi-spectral images from different viewing angles, resulting in a redundancy in the geometric reconstruction. This redundancy is of great importance to the reliability of automated generation of DSMs. Although it is possible to perform matching using more images (panchromatic, RGB and NIR), in this study a triplet matching using only panchromatic images is performed.

A hierarchical coarse-to-fine approach has been chosen for triplet matching due to its advantages that it is fast and simple. Matching is performed at pixels of extracted features mainly because they are the abstract of the scene; also, the processing is fast and robust. Multi-view matching can derive a robust approximation through the intersection of more than two image rays. It also can increase the precision and reliability, and has less problems caused by radiometric differences.

3.1 Image pre-processing

Due to the high dynamics of an airborne environment, the raw images (Level 0) have to be rectified. The tight integration of GPS, IMU and focal plate allows GPS and IMU data to be recorded together with the ADS40 high-resolution panchromatic and multi-spectral images during the fight in order to facilitate ground processing. GPS/IMU data from the Applanix system are post-processed to provide orientation data for each image line. The camera calibration and the orientation data are used to generate rectified ADS40 images (Level 1). The ADS40 level 1 images are rectified onto a height plane and the differences of scale, rotation and shear that might exist in raw images (Level 0) are removed to a large extent.

Rectified images (Level 1) of three panchromatic channels are further processed by using a Wallis filter in order to obtain a better contrast enhancement.

3.2 Generation of image pyramids

A fast matching approach is very important for practical applications, especially when a multi-view matching is performed, in which a large amount of data has to be processed. For ADS40 high-resolution images, one strip corresponds to three panchromatic channels (forward, nadir and backward). Since each image could be kilometres long, which corresponds to more than 1 Gigabyte, the processing time should be considered and the memory should be efficiently managed. In order to manage and process this large amount of data efficiently, a coarse-to-fine matching strategy may be a good choice. In a hierarchical coarse-to-fine architecture, images are represented in a variety of resolutions, leading to an image pyramid. Results achieved on one resolution are considered as approximations for the next finer level. Thus, the search range in each level can be restricted within a very small area and the matching process is fast. The upper levels of the pyramids are ideal to get an overview of the image scene. The details can be found down the pyramid at higher resolution. The coarse-to-fine strategy also reduces the necessity for initial values for the points to be matched.

In this study, all the images are radiometrically processed using a Wallis filter at each level.

3.3 Feature extraction

The distinction between different matching primitives is probably the major difference between the various matching algorithms. These primitives fall into two broad categories, windows composed of gray values (area-based matching*)*, and features extracted in each image (feature-based matching). Many researches demonstrated that matching methods based on features extracted from images have much better performance especially for artificial structures (Shibasaki et al., 2003). Feature-based matching is also a possible matching speed-up.

Edges in images are areas with strong intensity contrasts, i.e. a jump in intensity from one pixel to the next. Edges characterize boundaries and are therefore a problem of fundamental importance in image processing. Edge extraction significantly reduces the amount of data and filters out useless information, while preserving the important structural properties in an image.

Canny edge detection algorithm is known as the optimal edge detector (Canny, 1986). Canny edge detector was developed by introducing many processing techniques and is one of the most practical and commonly used techniques today. It follows a list of particular criteria to improve traditional methods of edge detection. Some researches were carried out to compare the performance of Canny edge detector to that of other edge and point extractors (Fisher et al., 1994, Richard et al., 2000, Pateraki and Baltsavisa, 2002). Results showed that Canny algorithm performed better than other algorithms in terms of processing time and density.

We selected a feature-based matching approach in our study. Canny edge detector is used to extract feature points as matching primitives in each image individually prior to the matching process. Feature extraction is performed after pre-processing of three panchromatic images at each pyramid level. Edge features are extracted as dense as possible in order to facilitate the subsequent processing. All calculations are performed on 16 bits data, so that the full image information is exploited during processing.

3.4 Triplet matching

Feature transmission

Feature-based matching is performed from a higher pyramid level to a lower level. The matched feature points in the higher level are passed to the lower level to guide the search process for fine matching. The feature transmission is illustrated in figure 3.

Geometric constraint

One major disadvantage of three-line push-broom sensors is the weak geometric characteristics. Due to the non-epipolarity of line scanner images, even after rectification, errors due to line perspective geometry and aircraft movements are not removed completely and depend on the height of the scene above projection plane. The epipolar geometric characteristics of the ADS40 rectified images is already analysed in the literature (Pateraki and Baltsavisa, 2003). Thus, the quasi-epipolar geometric constraint can be applied in the process of feature points matching, where the searching for the candidate homologous points is restricted within a search area along the quasi-epipolar line. This reduces ambiguity and computational cost.

In a quasi-epipolar constrained matching approach, the approximate height can be obtained by an initial forward intersection. The search range in image space is transformed to a search range in object space. The search step in object space is calculated corresponding to one pixel step in image space.

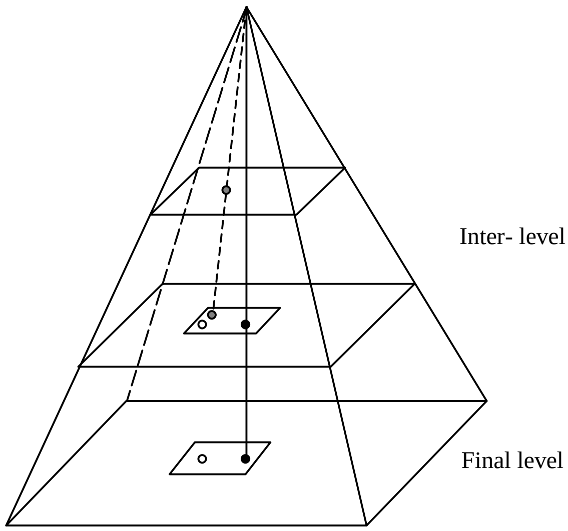

Figure 3. Image pyramids and feature transmission

Matching implementation

Multi-view matching has the advantage that a strong geometric constrain is available for disambiguation, which enables a more reliable and precise performance.

Three panchromatic images are used for triplet matching. Figure 4 shows the sub-scenes of the ADS40 panchromatic images used in this study. The nadir view is used as template image, while the forward and backward views are used as patch images since the combination of nadir and backward view is effective for left occlusion and the combination of nadir and forward view is effective for right occlusion. The forward and backward views are matched with the nadir view. The known exterior orientation is used to enforce geometric constraints, restricting the search space along quasi-epipolar lines between each pair of views. The ADS40 sensor model developed by Leica Geosystems is used in all transformations among image space, object space and focal plane. The matching similarity of the corresponding feature points is assessed by normalized cross-correlation. The position of the matching points in object space are obtained directly by spatial forward intersection of only good matching rays, while the poor matching rays are discarded.

4. CONCLUSION AND FETURE WORK

We introduced a hierarchical coarse-to-fine matching strategy for ADS40. Triplet panchromatic images are utilized in order to acquire a reliable matching result. The performance of the algorithm is highly dependent on the existence of well-defined

  

Figure 4. Sub-scenes of the ADS40 panchromatic images. (a): Forward. (b): Nadir. (c): Backward.

features in the input images. The precise exterior orientation of ADS40 facilitates a geometric constrained matching and speed up the matching processing. This is just an initial step of our research and development. Some of the processes are only implemented in a simplified form and need to be improved. Future works include the improvement of the multi-view matching algorithm. Multi-spectral images will be involved into the matching process in order to achieve the redundancy and more reliable results. The influence of vegetation and shadow will be considered. Improvements also include terrain surface modelling and reliability evaluation. Comparisons among different matching methods quantitatively should also be necessary.

References

Canny, J., 1986. A computational approach to edge detection, IEEE Trans. Pattern Analysis Machine Intelligence, Vol. PAMI-8, No. 6, pp. 679-698.

Fisher, B., Perkins, S., Walker, A., Wolfart, E., 1994. Hypermedia Image Processing Reference, http://www.cee.hw.ac.uk/hipr/, Department of Artificial Intelligence, University of Edinburgh, UK.

Nonin, P., 2003. Automatic extraction of digital surface models from airborne digital cameras. Proceedings of the 6th conference on Optical 3-D Measurement Techniques, Zurich, Switzerland, September 22-25, Vol. I, Part I, pp. 106-113.

Pateraki, M., Baltsavisa, E., 2002. Adaptive Multi-Image Matching Algorithm for the Airborne Digital Sensor ADS40. Asian Conference on GIS, GPS, Aerial Photography and Remote Sensing "Mapasia 2002", Bangkok, Thailand, 7-9 August.

Pateraki, M., Baltsavisa, E., 2003. Analysis and Performance of the Adaptive Multi-image matching Algorithm for Airborne Digital Sensor ADS40. ASPRS Annual Conference 2003, Anchorage, AK, USA, 5-9 May.

Reulke, R., Franke, K., Pomierski, T., Schonermark, M., Tornow, C., Wiest, L., 2000. Target related multispectral and true colour optimization of the colour channels of the LH Systems ADS40. International Archives of Photogrammetry and Remote Sensing, Vol. 33, Part B1, pp. 244-250.

Ricard, D., Hansen, H. H., Wozniewski, M., 2000. Linear Feature Extraction and Description, http://www.cs.mcgill.ca/~mwozni/graphics_proj/, School of Computer Science, McGill University, Canada.

Sandau, R., Braunecker B., Driescher, H., Eckardt, A., Hilbbert, S., Hutton, J., Kirchhofer, W., Lithopoulos, E., Reulke, R., Wicki, S., 2000. Design principles of the LH Systems ADS40 airborne digital sensor. International Archives of Photogrammetry and Remote Sensing, Vol. 33, Part B1, pp. 258-265.

Shibasaki, R., Tsuno, K., Morita, K., Chen, T., 2003. Triplet-matching for DEM generation with PRISM, ALOS. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXIV, Part. 7/W14.

Tempelmann, U., Borner, A., Chaplin, B., Hinsken, L., Mykhalevych, B., Miller, S., Recke, U., Reulke, R., Uebbing, R., 2000. Photogrammetric Software for the LH Systems ADS40 Airborne Digital Sensor. International Archives of Photogrammetry and Remote Sensing, Vol. 33, Part B2, 552-559.