Research on Detection Technology for the Changes of Buildings by High Resolution Remote Sensing Image

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Abstract—Remote sensing is one of the most effective monitoring technologies for space change at home and abroad. This paper was designed to investigate the application methods of aerial and space remote sensing techniques in urban building change monitoring. It also proposed an urban spatial data updating method combining the InSAR technology and aerospace remote sensing for large-scale data updating and aerial photogrammetry technology for small-scale key data updating. Through simulation experiments of watershed-based image recognition and monitoring, observation and comparison, this paper adopted a watershed-based segmentation algorithm for GPU and its application to change recognition of urban building images.

1. Introduction
Economic globalization has been accelerating with urbanization, but it has also caused dense population, traffic congestion, air pollution and difficulties in sharing superior resources. The original urban management failed to adapt to the accelerated urbanization, and it is subject to backward management means, information access lag, ill-conceived planning and the like. In order to construct sustainable urban development and address the urgent problems of urban management, the concept of "territorial spatial planning" was applied.

How to objectively and quickly monitor the change of urban spatial forms, especially when the change has become a hot topic and a knot in current research, is of significant importance. The progress in remote sensing and camera technology enables photogrammetry to advance by leaps and bounds and therefore makes it possible to monitor urban building changes with high resolution remote sensing data. In China, the research on building change monitoring has started since the 1990s, mainly via remote sensing with optical satellite image data. After years of technological development and progress, the monitored polygon has been gradually reduced, and the monitored objects have been refined. In the urban-rural fringe, the occupation of cultivated land by building land can be monitored using optical satellite images. However, optical satellite image, which are prone to long acquisition period and weather changes, cannot be acquired in cloudy and rainy areas as scheduled, resulting in the failure of periodic monitoring. Another difficulty is to detect the floor commonly added to the roofs in “villages” inside cities using optical satellite images.
2. Advantages of building change monitoring with high resolution remote sensing images

2.1. Data production technology of high resolution remote sensing

In foreign countries, data acquisition equipment and post-processing software of oblique photography have experienced more than ten years of development. Trimble AOS, IGI’s Penta-Digicam system, and VisionMap A3 are easily available in the international photogrammetry exhibitions and camera markets. In China, on the other hand, there is no more efficient and perfect 3D modeling solution for oblique photography, except the representative engineering applications of the post-processing technology by Eastdawn and HuaZheng. But their post-processing modeling needs LIDAR data, with a difficulty in establishing the process and standards for the coproduction of DOM, DEM, TDOM, DSM and real 3D model products with oblique aerial photography. The research is a technological innovation of oblique aerial photography.

2.2. Image recognition

Watershed is a region-segmentation-based image segmentation algorithm, inspired by the process of immersion simulation. Because a watershed change associates the object in the input image with the minimum point highlighted using a marker, where the hilltop line corresponds to the boundary of the object, the watershed transform can be used to segment contiguous regions into distinct objects. Compared with other segmentation algorithms, watershed boasts continuous boundary, high precision and fast speed, facilitating the extraction of building features from a large number of aerial images.

2.3. Change monitoring technology

Interferometric Synthetic Aperture Radar (InSAR) is a novel technology for earth observation from space developed in the recent decade, and it is also a unique space geodesy methodology based on surface observation. By using the phase data of spaceborne or airborne radar signals, InSAR can be employed to extract accurate three-dimensional data of a large area on the earth surface in all weather and all day, with high spatial resolution and basically not affected by climate conditions. At present, small surface deformation can be detected via Differential InSAR (DInSAR) an InSAR extended technique that has shown great technical advantages and application potential in the studies on seismic deformation, volcanic movement, glacier drift, urban subsidence and mountain landslide.

On the basis of InSAR-guided high-resolution building height extraction based on time series, the high-precision and high-density DSM images obtained during the research, and the building height data was first extracted from sequential multi-phase high-resolution InSAR images, and then used to determine illegal buildings and their suspected polygons.

3. Technical route for monitoring building changes from high resolution remote sensing images

3.1. Integrated oblique aerial photography production process route

To complete all tasks with high quality and efficiency in a short time and ensure the quality of the results must rely on the mature, advanced surveying and mapping technology, adopt the high-resolution remote sensing image data integrated mapping system "PixelGrid" for data processing, and use cluster distributed parallel processing technology, automatic and efficient aerial image block adjustment and image matching to automatically generate DSM and DEM data, and quickly correct and generate DOM images. Then, preliminary TDOM was generated by using Photomesh and DSM data, and finally TDOM products were obtained.

The process was shown below:
3.2. Technical route of building change monitoring

This project aimed to monitor the changes of illegal buildings in a city using multi-source remote sensing data. By obtaining stereo image pairs of high- and extremely high-resolution optical remote sensing satellite images, urban DOM and DSM data can be quickly produced. Based on the process route of integrated oblique aerial photography production, the plane changes and elevation changes of urban buildings can be quickly found. Through the combination of multi-source remote sensing satellites, the city's multi-frequency imaging data can be quickly acquired. Then the high-frequency monitoring of building changes can be realized by means of automatic analysis, manual interpretation and on-site verification.
3.3. **Parallel watershed image segmentation technology route**

The watershed algorithm was used to segment fifty images with 2MB file size on the computer configured with 2 cores (2.1G) and 4G of memory. It took about 25 seconds. As a professional image processing and computing unit, GPU has been widely used in industry, geographic information, AR and VR. Therefore, the program flow was encapsulated in this paper to calculate the raster pixels of images using GPU, without any change in the watershed algorithm. The specific flow was as follows:
Batch processing of the fifty images took about 600 milliseconds, an efficiency improvement of about 40 times.

4. Experimental results and analysis
Multi-phase real-life 3D models and DSM products were obtained via oblique photogrammetry, and compared to detect the change of building height.

In the sample graph, the real-life 3D model of the oblique images before benchmarking was on the left side, while that after benchmarking was on the right side, illustrating that the roofs have been covered with illegal buildings, as shown below:

![Figure 4 Comparison of real-life 3D models](image_url)

The following figure is a large-area comparison chart.
It can be inferred from the above figures that the real-life 3D model and DSM data of two phases quickly produced by using oblique images can help monitor the plane and elevation changes of urban buildings in the key sections near the key projects and the planned development areas quickly and finely. The monitoring accuracy can reach 50 cm in plane and 30 cm in elevation.

5. Conclusion
The latest oblique photogrammetry was adopted in the spatial change monitoring of urban buildings. In addition, in case of a large flight area which involves large capital investment, radar satellite image data should be considered as a supplementary monitoring data source for small-scale oblique photogrammetry and large-area optical satellite image data, in order to meet the needs of urban construction change detection. This paper proposed an integrated process flow through which the basic data of land space-time information can be generated using oblique photogrammetry and applied to urban construction management. Specifically, the process flow includes using oblique photogrammetry to obtain image data and produce DOM, DEM, TDOM, DSM, real-life 3D models and their monomer products, storing and regularly updating the database, automatically discovering, updating and managing new buildings by analysis with the computer, and monitoring illegal buildings, illegal occupation of roads, adding stories to building in villages inside cities, etc.

References
[1] Jia Yonghong, Xie Zhiwei, et al. A new change detection method of remote sensing image [J]. Geomatics and Information Science of Wuhan University, 2016, 41(8)
[2] Zhao Hong, Du Mingcheng, et al. Production process of the smart city 5D product based on oblique photograph [J]. Engineering of Surveying and Mapping, 2016, 25(9)

[3] Zhao Yi, Qian Le, Yang Kui. Discussion of InSAR accuracy in the urban building subsidence monitoring [J]. Urban Geotechnical Investigation & Surveying, 2015 (3): 115-119

[4] Yang Fan. Digital Image Processing and Analysis [M]. Beijing University Press, 2007: 10 ~ 140.

[5] Qin Jie, Qiao Tao. Research on the application of digital image processing technology in audio-visual evidence [J]. Legality Vision, 2015,26 (34): 284-285

[6] Zhou Sujuan, Tu Yongqiu, Huang Zhanpeng, et al. Research on the application of digital image processing technology in TCM informatization [J]. Chinese Journal of Information on Traditional Chinese Medicine, 2012,19 (05): 103-106

[7] Hao Wenhua. MATLAB Image Processing Application Tutorial [M]. Beijing: China Water & Power Press, 2004: 20-380.