APPLICATIONS OF SPOT-5 IMAGERY IN SURVEYING AND MAPPING OF WEST REGIONS IN CHINA

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ABSTRACT:

During the past 50 years, there are no topographic maps at scaled of 1:50,000 in the West Regions of China. Beside the extremely adverse environmental condition of the regions, the poor surveying and mapping technology is an important factor to cause the situation. This kind of present condition limited the Development of the West Regions and embarrassed the economic and social sustainable development of China. For solve this kind of predicament, the project of Surveying and Mapping of the West Regions in China was launched in 2006 and Remote Sensing techniques are applied to the project. SPOT-5 imagery is one of important data sources of the project. The paper discusses the applications of SPOT-5 images in Surveying and Mapping of West Regions in China. Within the SPOT constellation, SPOT-5 is the most innovative satellite. SPOT-5 HRS, HRG and multi-spectral images are applied in the project of Surveying and Mapping of West Regions in China. SPOT-5 images orientation is studied firstly. Secondly, mapping from SPOT-5 HRS stereo image pairs in seamless mapping system is also given. Thirdly, DEM generation by two means are introduced. Finally, DOM from SPOT-5 HRG and multispectral imageries are also introduced.

1. INTRODUCTION

During the past 50 years, there are no topographic maps at scaled of 1:50,000 in the West Regions of China. Beside the extremely adverse environmental condition of the regions, the poor surveying and mapping technology is an important factor to cause the situation. This kind of present conditions limited the development of the west regions and embarrassed the economic and social sustainable development of China. For solving the kind of predicament, a national project of Surveying and Mapping of the West Regions in China was launched in 2006 and Remote Sensing techniques are applied to the project.

To obtain stereoscopy with images from satellite scanners, two solutions are possible (Toutin, 2001):

1. The in-track stereoscopy from the same orbit using fore and aft images; and
2. The across-track stereoscopy from two different orbits.

The latter solution was more used since 1980: firstly, with Landsat from two adjacent orbits (Simard,1983), then with SPOT using across-track steering capabilities (Denis, 1986), and finally with IRS-1C/D by "rolling" the satellite (Gopala Krishna et al., 1996). In the last few years the first solution got renewed popularity with the JERS-1's Optical Sensor (OPS) (Maruyama et al., 1994), the German Modular Opto-Electronic Multi-Spectral Stereo Scanner (MOMS)(Ackerman et al., 1995; Raggam et al., 1997; Kornuset al., 1998), the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) (Tokunaga et al., 1996), the Indian Cartorsat-1, the Taiwan Formosat-2, and most of the agile high-resolution satellites (Toutin, 2004a).

Within the SPOT constellation, SPOT-5 is the most innovative satellite. SPOT-5 was launched on 4th May, 2002 by Arianespace from the Kourou Space Centre in French Guyana. After completing two months of in-orbit tests it became fully operational in July 2002. It comprises two identical optical High Geometric Resolution (HRG) imaging instruments and the High Resolution Stereoscopic (HRS) imaging instrument (Bouillon et al., 2002), which enables both stereo solutions to be performed and addressed. The HRG instruments offer an oblique viewing capability and the viewing angle being adjustable through ±27° relative to the vertical enables the generation of across-track multi-date stereoscopy from two different orbits. The base-to-height ratio (B/H) is thus between 0.6 and 1.1. On the other hand, the HRS instrument offers fore-and-aft viewing capability for in-track stereoscopy from the same orbit. The HRS instrument with a telescope viewing angle of ±20° is dedicated for taking simultaneous stereo-pairs with B/H of around 0.80. The stereo-pairs of 120km swath and 600km long (maximum length) are acquired in panchromatic (black and white) mode with a sensor spatial resolution of 10m but with 5m ground sampling distance (GSD) in the line direction. Users could then apply traditional three-dimensional (3D) photogrammetric techniques with the stereo-images to extract accurate planimetric and elevation information and collect cartographic maps. However, same-date in-track stereo-data acquisition gives a strong advantage to multi-date across-track stereo-data acquisition because it reduces radiometric image variations, and thus increases the correlation success rate in any image matching process (Toutin, 2001) and reduces the workload of tuning the tone of DOM. Moreover other payload packages such as the same Vegetation instrument as on SPOT-4,

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and the DORIS instrument, for greater orbital accuracy are contained in SPOT-5 System.

SPOT-5 images have been taken as the main data source in the national project of Surveying and Mapping of the West Regions in China. Applications of SPOT-5 imagery in the project are introduced in the paper.

2. IMAGES ORIENTATION

For the orientation of the HRS and HRG images there are two approaches. The first one is a rigorous sensor model for pushbroom linear array sensors (Poli, 2003). The alternative approach is based on the RPC (Rational Polynomial Coefficients) model (Zhang et al., 2004). The principle of the latter is as the following. At first 3D grids of points were generated for a set of elevation levels from the image-space coordinates, using the given camera model parameters, the ephemeris and the attitude data attached in the metadata file. Then the RPC coefficients were determined for each image by a least-squares approach and without GCPs. After the RPC generation, a block adjustment was performed in order to estimate 6 parameters for each image (affine transformation) to remove remaining systematic errors. In the project of Surveying and Mapping of the West Regions in China applies the latter approaches for SPOT-5 images orientation.

Two experiments were carried out to evaluate whether the SPOT-5 images are competent for cartographic maps at scaled of 1:50,000. The first experiment applied two SPOT-5 HRS stereo image pairs in two adjoining orbits to orientation for accuracy evaluation. One covers the ground extension about 120×580 km^2 and another covers about 120×508 km^2. A total of 77 object points measured with surveying methods were applied for the bundle adjustment of the RPC model for SPOT-5 HRS images in the experiment.

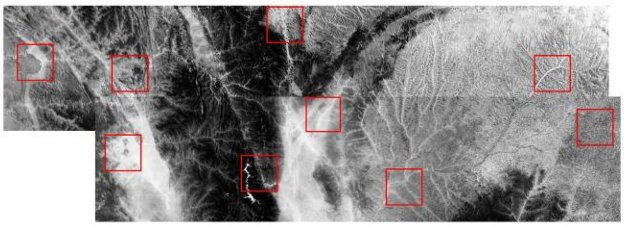


Figure 1 HRS stereo image pairs and GCPs applied for accuracy evaluation in first experiment

In the experiment, different schemes of bundle adjustment were carried out by selecting different number of Ground Control Points (GCPs) and Check Points (CPs) from the total 77 object points, and compared the orientation accuracy in these schemes. The results are given in the following table 7.

GCPs/CPs	GCP RMS Residuals (m)			CP RMS Errors (m)		
	X	Y	Z	X	Y	Z
0/77				22.35	42.63	7.14
4/73	4.07	0.67	1.42	6.59	6.41	4.94
6/71	0.71	1.20	0.47	6.34	5.48	4.01
77/0	5.65	4.84	3.64			

Table 1. Results from the least-square bundle adjustment of the RPC model for SPOT5 HRS stereo-pairs.

The last experiment applied a SPOT-5 HRS stereo pair and a SPOT-5 HRG image covering the same ground area and carried on the least-square bundle adjustment of the RPC model for the HRS stereo pairs and the HRG image.

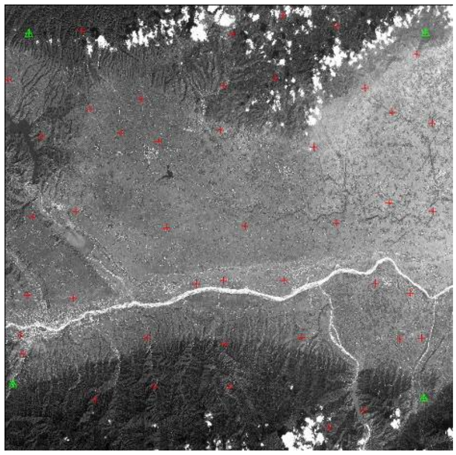


Figure 2. HRG image and distribution of tie points and GCPs

In the experiment, a total of 48 object points measured with surveying methods were applied for the different tests on the bundle adjustment of the HRS and HRG stereoscopic pairs. 4 of these object points distributed at the bound of corresponding area were selected as GCPs and others were selected as CPs. Two orientation schemes were carried out and compared the results of two schemes. In the first scheme only the SPOT-5 HRS stereo images are applied for bundle adjustment. In another scheme the SPOT-5 HRS stereo images and HRG image were applied for bundle adjustment.

	GCPs			CPs		
	X	Y	Z	X	Y	Z
HRS	5.177	2.008	2.151	5.213	3.439	4.248
HRS & HRG	3.165	2.401	1.047	2.764	2.220	2.467

Table 2. Result from the least-square bundle adjustment of the RPC model for HRS and HRG.

The results of experiments indicate that SPOT-5 images are competent for mapping topographic map at scaled of 1:50,000 in West Regions of China.

3. APPLICATIONS

Once SPOT-5 images are orientated, coordinates of objects in object-space are able to be extracted from one or more stereo image pair. Digital Line Graph (DLG), Digital Elevation Model (DEM) or Digital Surface Model (DSM) and Digital Orthorectification Map (DOM) are classical products of digital photogrammetric processing. The generations of DEM/DSM, DLG and DOM from SPOT-5 images are introduced in the following sections.

3.1 DEM/DSM

Digital Surface Models (DSMs) are often referred to as the models for the first reflective or visible surface, while Digital Elevation Models (DEMs) are usually referred to the bare earth, i.e. without trees, buildings or other features on the actual surface. They are classical and common products from (digital) photogrammetric systems. In modern map production, DSMs/DEMs have become unavoidable information for scene analysis and understanding, for change detection, for GIS database updating and, for cartographic 3D feature extraction and reconstruction.

DEMs are usually generated by automatically matching dense pattern feature from two or more images in modern digital photogrammetric systems. In the past years, due to the high spatial resolution of recent airborne/spaceborne sensors in the visible and infrared spectrum, a large number of researchers around the world have investigated the extraction of elevation and/or the production of DSMs/DTMs. A wide variety of approaches have been developed, and automatic DSM/DTM generation packages are in the meanwhile commercially available on several digital photogrammetric workstations (Zhangli, 2005). An automatic DEM/DSM generation package of ImageInfo® developed by Chinese Academy of Surveying and Mapping is made use of in practice production in the Surveying and Mapping of the West Regions in China. The package provides multiple primitive multi-image (MPM) matching function and has the ability to provide dense, precise, and reliable results. Generally speaking, DEMs/DSMs are extracted by SPOT-5 HRS stereo images. However, it is necessary that applying both SPOT-5 HRG and SPOT-5 HRS images to extract DEMs/DSMs of complexity terrains. The figure 3 is a shaded relief map of DSMs generated from SPOT-5 HRS and HRG images. After generated, DEMs/DSMs are overlapped on stereo models and are manually edited the mismatching areas by operators. The workloads of edit are very low because there are few mismatching in DEMs/DSMs generated by the above extraction package.

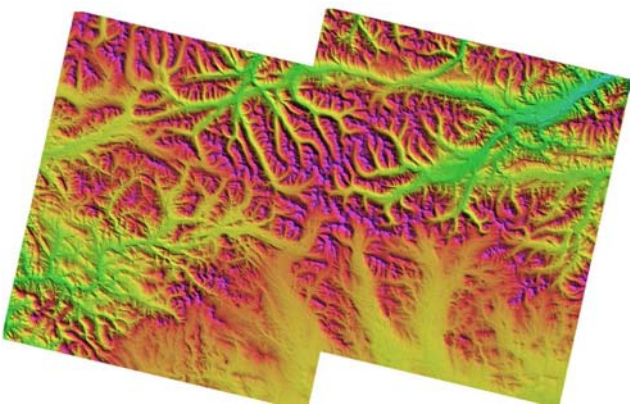


Figure 3. Shaded relief map of DSM generated by ImageInfo®

The performance of image matchers does by far not live up to the standards set by manual measurements, so there is another manual way to generate DEMs/DSMs. Topographic maps are collected from SPOT-5 HRS stereo-pairs by manual stereoscopic measurements. Then DEMs are automatically generated from these manual measured topographic maps by a new algorithm of interpolating DEM which is developed by Supresoft Inc. The algorithm is able to keep the consistency between DEMs and corresponding topographic maps. The figure 4 illustrates the effect of DEM interpolation and compared the difference between the new algorithm and a traditional algorithm. The comparisons are made as the following steps: two DEMs are generated from a manual measured contour map by the new algorithm and a traditional algorithm, respectively. Then two new contour maps are extracted from the two new generated DEMs. Finally the effect and the difference are compared by overlap new generated contour maps and the original contour map, respectively.

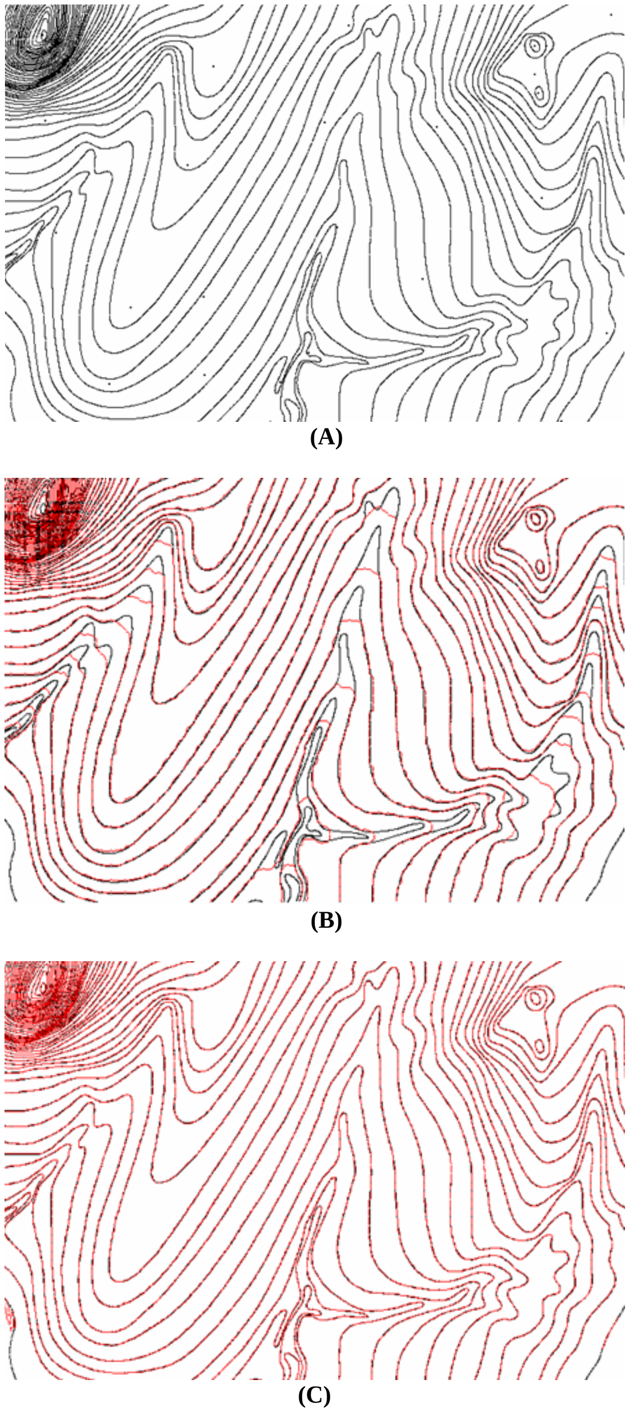


Figure 4. Effect of the new algorithm and comparison between the new algorithm and a traditional algorithm. (A) is a manual measured contour map. (B) is the overlap figure between original contour map and a contour map created by a traditional algorithm. (C) is the overlap figure between original contour map and a contour map created by the new algorithm.

3.2 DLG

DLG is a very important product of digital photogrammetric systems and it is extensively used by geospatial-related fields. DLG is a pivot in the project of Surveying and Mapping West Regions of China.

SPOT-5 HRS imagery is mainly used for mapping topographic maps by manual stereoscopic measurements. Because the ground resolutions in two directions of images are different, the SPOT-5 HRS images should be performed geometric transformations such as zooming and rotating. A scene of SPOT-5 HRS stereo pair covers a 120km*600km area in the ground. Topographic mapping from SPOT-5 HRS stereo pairs challenges the current workflow of the traditional digital photogrammetry, so a new mapping workflow is proposed for mapping topographic map from high resolution satellite imagery.

In practical production, a new mapping system for high-resolution satellite images called Seamless Mapping System (SLM) developed by Supresoft Inc. is applied. The mapping system is built on a high-speed network and with the distributed processing capability and with the help of the system, collaboration of mapping among different operators is supported. In the mapping system, Mapping from SPOT-5 HRS stereo pairs are firstly divided into a certain of sub-tasks according to task planning strategies. The usual strategy, as illustrated in figure 5, is to divide the mapping into a lot of standard map sheets according to these map sheets' ground bounds.

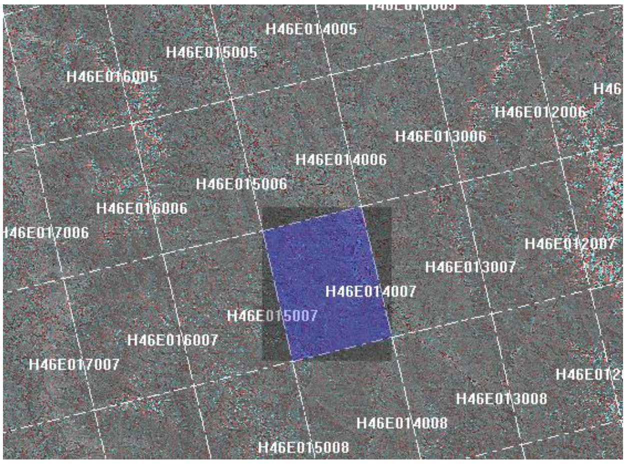


Figure 5. Map sheet dividing strategy in Seamless Mapping System.

Once mapping tasks are created at a server end and dispensed by administrators to operators for manually stereoscopic measurements, operators are able to access the related images and orientation data at their workstations. It is not necessary for operators to obtain all SPOT-5 HRS images instead of partial data of HRS images related to a map sheet. By the dividing strategy, mapping of a SPOT-5 HRS stereo pair is able to collaborate by many operators and more efficiently processed.

In order to solve the occlusions of objects on the HRS stereo images as shown in the figure 5, a HRG image and two HRS images are combined to form three stereo pairs for manual stereoscopic measurements.

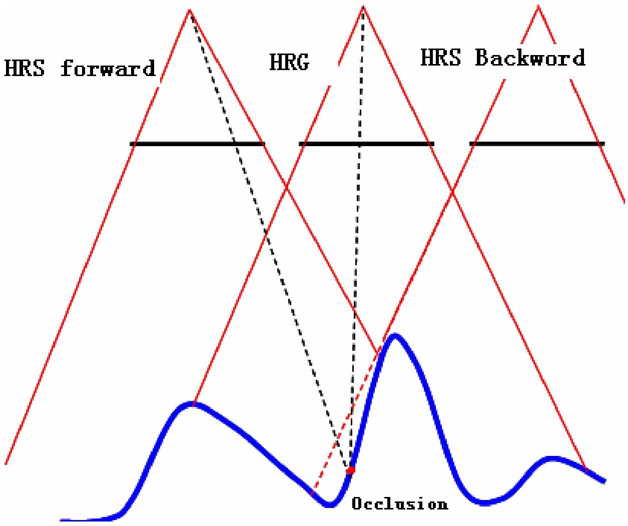
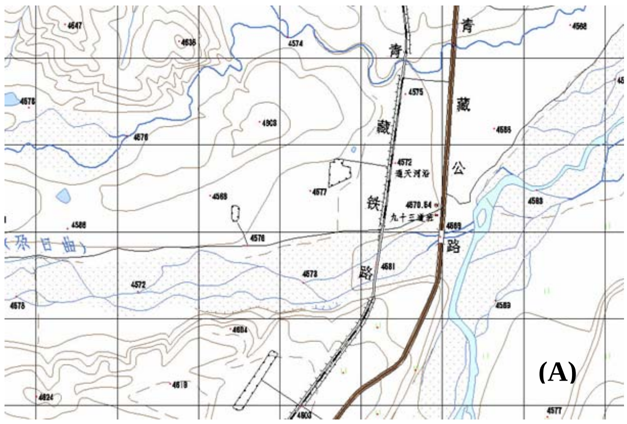


Figure 5. Combination of HRG and HRS images for stereoscopic measurements of DLG

Contours are main features of a topographic map. The workload of measurement of contours from stereo pair has about 80% of the whole works of mapping a topological map. The efficiency of producing topographic map depends on the efficiency of measuring contours. The most inefficient approach of measuring contour is surveyed manually. An alternative efficient approach is that contours are interpolated from DEMs/DSMs which are automatic extracted from HRS and HRG stereo pairs. By using the Multi-photo Geometrically Constrained Matching technique, DEM or DSM can be automatically extracted from SPOT-5 HRS and HRG imagery. Then contours are interpolated automatic from DEM, the workload of topographic map is consumedly reduced.

The figure 6 shows there DLGs of different geomorphic type collected from SPOT-5 HRS images and HRG images in the west regions of China.



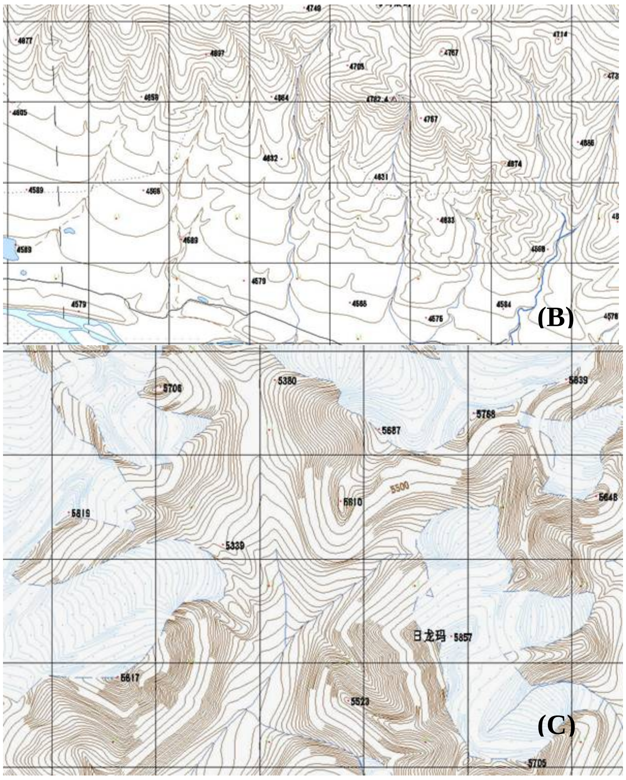


Figure 6. DLGs collected by stereoscopic measurements from SPOT-5 HRS and HRG image stereo pairs. (A) is a DLG of an alluvial flat area. (B) is a DLG of a hilly terrain area. (C) is a DLG of a glacial landform area.

3.3 DOM

DOM can be automatically produced from the oriented HRG imagery and DEM extracted from the HRS stereo pairs. The generated image from HRG imagery is panchromatic. For generating colour DOM, it is necessary to fuse HRG and SPOT-5 multispectral imagery. Because of lack of the blue component in SPOT-5 multispectral imagery, the paper proposes a method to generate colour DOM by fusing the HRG and SPOT-5 multispectral imagery. The basic idea of the approach is that the blue component is simulated from other components in multispectral imagery firstly and then adapts the standard IHS method to fusing HRG and multispectral imagery. The method is different from others. Orthorectification and fusion are performed at the same time, so the step of image registration is not necessary for fusion. However, the SPOT-5 multispectral imagery orientation must be done before the orthorectification and fusion. In order to orientating multispectral imagery, an orientated HRG image is used as a reference image and correspondences in the two images are automatically extracted by image matching technique. The ground coordinates of these correspondences are acquired from the orientated HRG image and a corresponding DEM. Then the multispectral image is automatically orientated by regarding the correspondences as GCPs.

Figure 7. Images orthorectificated and fused by HRG images and multispectral images. (A) is a fusion image of a hillock region. (B) is a fusion image of farmland area. (C) is a fusion of a mountain region

4. CONCLUSION

SPOT-5 images are extensively made used of in the national project of Surveying and Mapping of the West Regions in China. Firstly, with few GCPs, SPOT-5 images have good orientation accuracy for mapping topographic maps at scaled of 1:50,000. The kind of capability is helpful for reducing the numbers of ground control points surveyed in extremely adverse environmental conditions of the west regions in China. By using the Multi-photo Geometrically Constrained Matching technique, DEMs or DSMs can be automatically extracted from SPOT-5 HRS and HRG images. Colour DOMs are also automatically produced from HRG images and multispectral images. Because the physical geographic and natural environments of the west regions in China are execrable, it is not fully competent for the whole mapping tasks of the west regions that only using SPOT-5 images. However, SPOT-5 images are the main data source for the project and in practice productions most of DLGs, DEMs and DOMs are produced from them. It's obvious that SPOT-5 images, as a main data source, are playing important roles in Surveying and Mapping of West Regions in China.

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