EVALUATION OF IRS-P5 STEREO IMAGES FOR REVISION OF TOPOGRAPHIC 1:25000 SCALE MAPS

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ABSTRACT:

Nowadays because of high potential of satellite images, maps production procedure and their updating increasingly go towards using satellite photogrammetry. With regard to Iran's restrictions to access to suitable satellite images for production and revision of medium and large scale topographic maps, installation of IRS-P5 receiver in country provides a suitable opportunity for 1:25000 scale maps production and acceleration of their revision procedure. As far as, one of the basic problems using satellite images in maps production and their revision is their lower information content as compared with aerial images, in addition to evaluation of geometric accuracy of these images, in this paper we evaluate the information content of the IRS-P5 stereo images for production and revision of 1:25000 scale maps. The result of these evaluations show that the IRS-P5 stereo images, from the point of geometric accuracy, have the capability of 1:25000 scale maps revision, also, from the point of information content, have the capability of revision for some objects such as building blocks, roads, and vegetation cover. Revision of other objects in 1:25000 scale maps that are problematic in their identifying and extracting is completing using other mapping methods.

1. INTRUDACTION

With regard to the importance of 1:25000 scale maps as National Topographic Data Base in Iran, the necessity of having update information for making correct planning, also because of finishing of 1:25000 scale maps production project, one of the important executive organization worries, is revision of these maps (Jamebozorg, 2001). The advantages of using satellite images, high time consuming and high task volume of using aerial images in production and revision of maps and also flying problems in frontiers area, show the necessity of more evaluation and studying on satellite images more than ever. With regards to Iran's restrictions to access to suitable satellite images for production and revision of medium and large scale topographic maps, installation of IRS-P5 receiver in country provides a suitable opportunity for 1:25000 scale maps production and acceleration of their revision procedure. Therefore, it is necessary to evaluate on these images for production and revision of 1:25000 scale maps.

Generally, for evaluation of a satellite imagery system for production and revision of medium and large scale maps, the following criterion should be considered (Doyle, 1998):

- Capability of stereo imagery
- Efficient geometric resolution
- Possibility of access to suitable mathematical models in order to extract 3D information
- Information contents and capability of objects extraction related to necessary information in maps
- Compatibility with software and hardware systems in photogrammetry
- Management stability in continuous production, political independence and easy access to the productions
- Suitable price

The common method of 1:25000 scale maps production is using 1:40000 scale aerial images (Standards of 1:25000 scale maps). But the problems of aerial photogrammetry, lead the executives to using satellite images for revision of these maps (Jamebozorg, 2001). The following reasons make satellite images a promising source for map production and revision (Holland and Marshal, 2006, Khairi, 2003);

- With joining GPS/INS to remote sensing satellite, the effectively of this system become more
- %100 overlap and B/H more than 1 is possible
- Images acquisition from the whole world without regard to the natural geography and political problems is possible
- The covered area with each satellite image is equal to the covered area with multiple aerial images
- Access to repetitious and periodic information, is a advantage for recording changes in a area when clouds is obstacle for imagery
- We can receive satellite images during the year
- With regard to the multi spectral images, ability of interpretation is more through the combination of spectral features of different phenomenon and can produce variable images
- There is no expenses except the expense of launch and primary expenses, (related to the countries that have this technology)

- The step of image processing isn't time consuming
- The large covered area with each satellite image will cause the elimination of block adjustment and mosaic production
- Needing to less control point and having orbital information that can be used as exterior orientation parameter or primary values
- With access to high resolution satellite images, these images can be replaced or complemented for aerial images for mapping
- The facility of obtaining stereo images with using tilted mirror

Of course beside these advantages, satellite images also have some defects;

- Receiving stereo images with regards to problems such as existence of clouds or snow and sometime overlapped image are related to different season that cause problems in 3D model production and object extraction
- Resolution of satellite images and their information contents are less than resolution of large scale aerial images and their information contents

The second problem maybe is most problematic issue in satellite imagery. This cause satellite images not to be replaced by aerial images but used as complement for aerial images. Although, it is maybe possible to ignore this problem because of the capability of receiving repetitious and periodic satellite images, fast image processing, large covered area with each satellite image and the advantages of access to far and restricted areas (Holland and Marshal, 2006). With regard to the advantages of satellite images and also access to the IRS-P5 stereo images, in this paper, geometric accuracy and information contents of these images related to the objects containing in 1:25000 scale maps are evaluated.

2. IRS-P5 STEREO IMAGES FOR REVISION OF MAPS AT 1:25000

2.1. IRS_P5 mission

IRS-P5 is a spacecraft of ISRO (Indian Space Research Organization), Bangalore, India. The objectives of the IRS-P5 mission are directed at geo-engineering (mapping) applications, calling for high-resolution panchromatic imagery with high pointing accuracies. The spacecraft features two high-resolution panchromatic cameras that may be used for in-flight stereo imaging. Hence, IRS-P5 is also referred to as CartoSat-1. In this mission, the high resolution of the data (2.5 GSD) is being traded at the expense of multispectral capability and smaller area coverage, with swath width of 30 km. The data products are intended to be used in DTM (Digital Terrain Model)/DEM (Digital Elevation Model) generation in such applications as cadastral mapping and updating, land use as well as other GIS applications. PAN-F (Panchromatic Forward-pointing Camera), featuring a fixed forward tilt of 26°PAN-(Panchromatic Aft-pointing Camera), it is fixed at an aft tilt of -5°. Each camera provides spectral range of 0.5 - 0.85 μm, a spatial resolution of 2.5 m, a swath width of 30 km, and data quantization of 10 bits. Stereo imagery is acquired with a small time difference (about 50 s) due the forward and backward look angles of the two cameras. The major change in imaging conditions during this time period is due to rotation of Earth. An algorithm for Earth rotation compensation is being used to eliminate the delayed observations of the two cameras (IRS user's Hand book).

2.2. The project of 1:25000 scale maps production

The primary study of the project of 1:25000 scale maps production started in 1987. Production of these maps started in 1991 and National Cartography Center could produce % 90 of these maps until July 2007. As mentioned before, because of flying problems other of areas related to frontiers.

Contour Interval	Accuracy in height 0.3×C.I.	Accuracy Planimetric (in 0.3 mm)	Resolution Planimetric (in 0.1 mm)
10 m	3 m	7.5 m	2.5 m

Table 1. Features of 1:25000 scale maps

3. PRACTICAL EVALUATION

3.1 The area of case study

For IRS_P5 stereo images evaluation, the stereo images of Shiraz are selected. For geometric accuracy evaluation, 113 full points are extracted from 1:2000 scale maps. With regard to the geometric accuracy of 1:2000 scale maps, it is necessary to mention that geometric accuracy of the full points is better than 60 cm (contour interval of 1:2000 scale maps is 2 meter).
In header file of IRS_P5 stereo images, we have 90 RPC (Rational Polynomial Coefficients) that these RPC calculated based on time and position of imagery (ERDAS IMAGINE 9.1 Online documentation). By using these RPC, geometric correction without any control points is possible. But by using a number of control points, we find out significant improvement in result. Access to these RPC in ERDAS IMAGINE 9.1 is possible that we used this software for evaluation of IRS_P5 stereo images geometric correction. We used Geomatica V8.1 for geometric correction evaluation by using polynomial equations and rational functions model without using RPC.

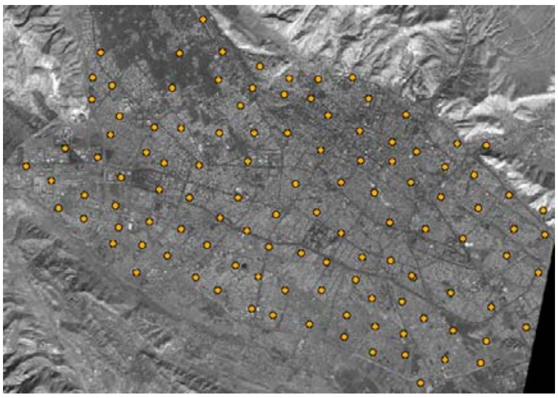

Figure 2. Distribution of control and check point in IRS_p5 image of Shiraz

3.2 The mathematical models using in this investigation

A rational function model and a 2D Polynomial equation model applied on the images used in this project. Brief descriptions of these models are given in the followings:

3.2.1 The 2D Polynomial equations

$$x = \sum_{i=0}^{n} a_i X^i Y^{(n-i)} \qquad y = \sum_{i=0}^{n} b_i X^i Y^{(n-i)} \qquad (1)$$

Where (x,y) are image coordinates and (X,Y,Z) are object coordinates.

3.2.2 Rational Function Model: In this model the image coordinates is determined from the ratio of two polynomials:

$$x = \frac{P1(X,Y,Z)}{P2(X,Y,Z)} = \frac{\sum_{i=0}^{m1}\sum_{j=0}^{m2}\sum_{k=0}^{m3} a_{ijk} X^i Y^j Z^k}{\sum_{i=0}^{n1}\sum_{j=0}^{n2}\sum_{k=0}^{n3} b_{ijk} X^i Y^j Z^k}$$

$$y = \frac{P3(X,Y,Z)}{P4(X,Y,Z)} = \frac{\sum_{i=0}^{m1}\sum_{j=0}^{m2}\sum_{k=0}^{m3} c_{ijk} X^i Y^j Z^k}{\sum_{i=0}^{n1}\sum_{j=0}^{n2}\sum_{k=0}^{n3} d_{ijk} X^i Y^j Z^k} \qquad (2)$$

Where

$$P1(X, Y, Z) = a_0 + a_1 X + a_2 Y + a_3 Z + a_4 XY + a_5 XZ + a_6 YZ + a_7 X^2 + \dots\dots\dots + a_{19} Z^3 \qquad (3)$$

Where (x,y) are normalized image coordinates and (X,Y,Z) are normalized object coordinates.

4. THE EVALUATION RESULTS OF IRS-P5 IMAGES

In this section we evaluate geometric accuracy and information contents of IRS_P5 stereo images.

4.1 Evaluation results of geometric accuracy of IRS-P5 images

NO. Check	NO. Control	RMSE (X)	RMSE (Y)	RMSE (X,Y)	RMSE (Z)
113	0	38.917	128.318	134.089	8.0901
112	1	1.4333	1.8690	2.3553	3.9956
111	2	1.4358	1.7945	2.2982	3.9319
110	3	1.5969	1.4592	2.1632	2.9985
109	4	1.5580	1.3200	2.0420	2.8847
108	5	1.5330	1.3371	2.0342	2.8112

Table 3: The results of geometric accuracy of IRS-P5 stereo images with using rational function model with RPC file

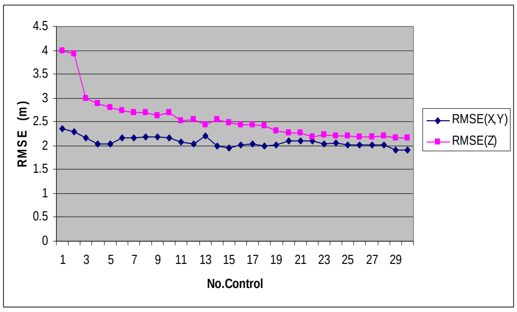

Figure 4: The results of geometric accuracy of IRS-P5 stereo images with using rational function model with RPC

As we see in table (3) because of using RPC, by choosing one control point, geometric accuracy increases significantly. By choosing 4 control points we achieved to desirable Accuracy. Also by using at least 3 control points, we achieved to height accuracy better than 3 meter that with regard to the height accuracy of 1:25000 scale maps, this result is in acceptable range.

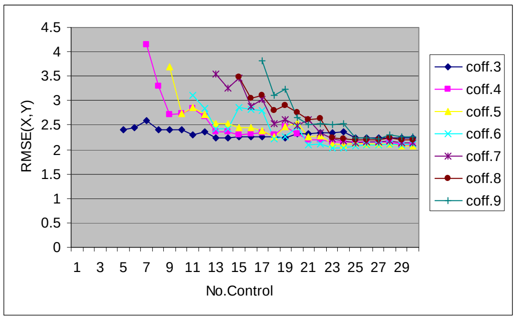

Figure 5: The results of geometric accuracy of IRS-P5 images with using rational function model without RPC file

By using third equation of rational function model without RPC, we obtained more smooth results compared with other orders. By choosing 25 control points, the results of whole rational function models will become converge.

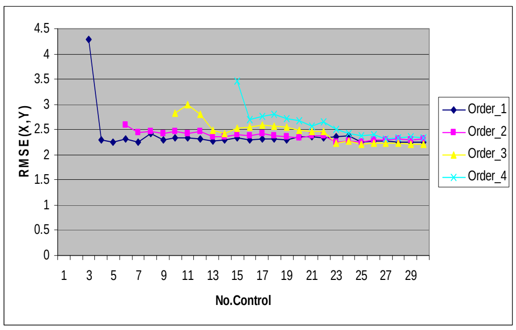

Figure 6. The results of geometric accuracy of IRS-P5 images with using polynomial equations

By using polynomial equations, approximately we achieve to the same results compared with rational function model without RPC. As we see the result of first order of polynomial equations is better than other orders.

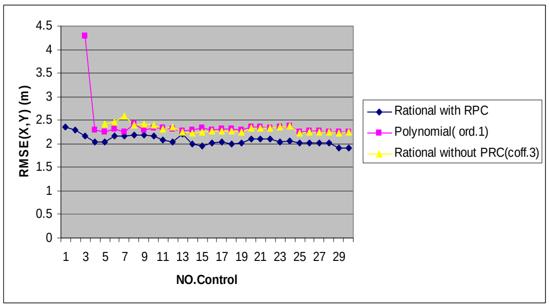

Figure 7. Comparison of the results

Results show that by choosing at least 5 suitable control points we can achieve to desirable geometric accuracy by using rational function model and polynomial equations.

Geometric correction results obtained from Rational function model by using RPC of IRS_P5 stereo images in get better result in respect to other methods in all conditions.

4.2 Information content evaluation of IRS_P5 stereo images respect to 1:25000 scale maps

In this section, objects of 5 main classes of 1:25000 scale maps evaluated based on information content.
Objects of building, Road, vegetation cover, hydrology, natural classes investigated based on object identification and extraction. This evaluation results are shown in the following tables:

Object Name	It's can be identify					It 's can be extract				
	No	Sometime	Often	Always	Didn't Exist	No	Sometime	Often	Always	Didn't Exist
Stadium				×					×	
Air Strip				×					×	
Tower				×					×	
Building Block				×					×	
Bridge				×				×		
Tunnel					×					×
Gas Station			×					×		
Water Well	×					×				
Gas or Oil Well	×					×				
Fence			×					×		
Utility Line	×					×				
Wall			×					×		
Single Building (to scale)				×			×			
Single Building (symbol)				×				×		
Toll Gate					×					×
Delimiter			×				×			
Storage (to scale)				×			×			
Storage (symbol)				×			×			
Ruins				×			×			
Square (to scale)				×					×	
Square (Symbol)				×					×	

Table 8. Building class

Object Name	It's can be identify					It 's can be extract				
	No	Sometime	Often	Always	Didn't Exist	No	Sometime	Often	Always	Didn't Exist
Railway					×					×
Trolley Line					×					×
Super highway				×					×	
Main Road				×					×	
Street				×					×	
Sideway			×					×		

Table 9. Road class

Object Name	It's can be identify					It 's can be extract				
	No	Sometime	Often	Always	Didn't Exist	No	Sometime	Often	Always	Didn't Exist
Watercourse			×					×		
Cut			×					×		
Embankment			×					×		
Ridge				×					×	
Sandy Dunes			×					×		
Salt Flat			×					×		
Rock			×					×		
Qanat		×					×			
Canal			×					×		
Pit And Pile			×					×		
Floodway			×					×		

Table 10. Natural class

Object Name	It's can be identify					It 's can be extract				
	No	Sometime	Often	Always	Didn't Exist	No	Sometime	Often	Always	Didn't Exist
Waterfall					×					×
Small Hydro.Eng.Structure					×					×
Large Water Bodies				×					×	
Spring		×					×			
River				×					×	
Dam				×					×	
Stream And Ditch				×				×		
Pool (to scale)		×					×			
Pool (symbol)		×					×			

Table 11. Hydrology class

Object Name	It's can be identify					It 's can be extract				
	No	Sometime	Often	Always	Didn't Exist	No	Sometime	Often	Always	Didn't Exist
Orchard				×				×		
Single Tree			×				×			
Woods			×				×			
Row Of Trees			×					×		
Cultivated Area				×				×		
Grass Land				×				×		
Bush Covered Area				×				×		
Forest				×				×		

Table 12. Vegetation covers class

5. CONCLUSION

As we saw in the tables of information content evaluation, the IRS_P5 stereo images evaluation result from the point of geometric accuracy and information content of main object such as roads, vegetation cover and some objects in building class show these images have ability of 1:25000 scale maps revision. For better objects identification and extraction for some objects such as objects of vegetation cover class, we can combine these images with multispectral images and obtain better result. Also ability of stereo viewing, provide possibility of better objects extraction such as wall, fence, bridge and also separation of highway from freeway that are different to be extracted from single image planimetric information. For some objects extraction that we have problems in their identification and extraction, it is necessary to make use of other mapping methods such as ground survey. Of coarse this problems is not related to satellite images merely, but also aerial images face to information content problem with less intensity such as utility line.

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