

COMPARATIVE CHARACTERISTICS OF DEM OBTAINED FROM SATELLITE IMAGES SPOT-5 AND TK-350

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ABSTRACT:

Production of various cartographic value-added products is based on use of DEM. In Russia stereo images TK-350 are used for DEM production. The main advantage of these images is their large format (30x45 cm), practical lack of angles of tilt ($\leq 1^\circ$), large range of photographic width (0.1 – 3.0D) and possibility to vary the value of along track overlap from 20% to 80%. SPOT-5 images are used for the same purpose, they are obtained immediately in digital form, their metadata are formed taking into account information from onboard equipment. Comparing to existing analogous satellites SPOT-5 has advanced navigational equipment. For precise determination of satellite's orbit parameters there is Doppler equipment DORIS which works over signals of Net of ground beacons IDS. This net includes about 60 radio beacons in many countries of the world on all continents. Star sensor SS is used for precise referencing of images. On the example of processing of SPOT-5 images in the frame of international experiment HRS-SAP (area 7, Iran) and TK-350 images using the same geo-data there is performed a comparison of produced DEMs in accuracy characteristics and economical parameters.

1. SOURCE DATA

On 29.07.2003 SOVINFORMSPUTNIK received the source data on CD-ROM for production of DEM over Rasht area of test site 7 Iran from CNES list presented in Denver in November 2002. The received materials include the following data:

CD-ROM with digital images of SPOT-5 stereopair in TIF format; metadata files for them in XSL format; fragments of test DEM and 28 maps in DGN format for Microstation 95 software package. Geodetic coordinates of DEM are given in zone 39 of UTM projection on WGS-84 ellipsoid, height datum Bandar Abbas. Date of survey 13.07.2002.

Corner Coordinates of Images (WGS-84):

Left Image Coordinates (pxl)

1.B = 37 ⁰ 37' 52" N	L = 49 ⁰ 12' 48" E	1	1
2.B = 37 ⁰ 22' 27" N	L = 50 ⁰ 31' 42" E	12000	1
3.B = 36 ⁰ 50' 59" N	L = 50 ⁰ 21' 31" E	12000	12000
4.B = 37 ⁰ 06' 20" N	L = 49 ⁰ 03' 09" E	1	12000

Right Image Coordinates (pxl)

1.B = 37 ⁰ 38' 18" N	L = 49 ⁰ 12' 25" E	1	1
2.B = 37 ⁰ 22' 16" N	L = 50 ⁰ 31' 09" E	12000	1
3.B = 36 ⁰ 50' 45" N	L = 50 ⁰ 20' 57" E	12000	12000
4.B = 37 ⁰ 06' 43" N	L = 49 ⁰ 02' 45" E	1	12000

Orientation Angles:

Orientation angle:	L 13 ⁰ .640525	R 14 ⁰ .424381
Incidence angle:	L 23 ⁰ .012006	R 22 ⁰ .466202

2. QUALITY ASSESSMENT OF SOURCE MATERIALS

The analysis of the received SPOT-5 stereo images showed that they are rotated 90⁰ clockwise. The dynamic range of image optical densities is very narrow – about 50 grayscale levels (Figure 1) thus forcing to use the procedure of maximal possible histogram stretch in ERDAS IMAGINE before processing.

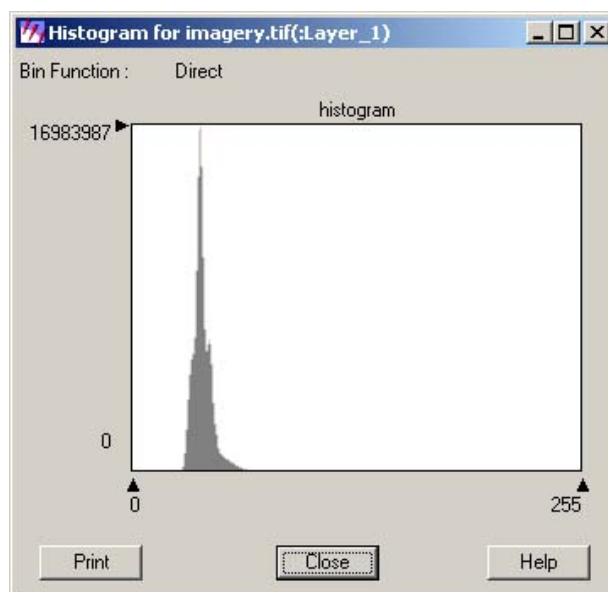


Figure 1.1. Histogram of the source SPOT-5 stereopair over Rasht, Iran (left image)

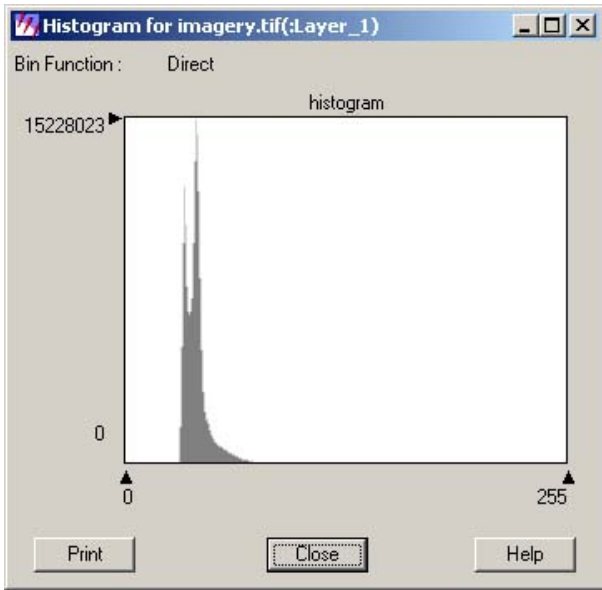


Figure 1.2. Histogram of the source SPOT-5 stereopair over Rasht, Iran (right image)

After performing of this procedure there appeared terrain features hidden from the eye on the source image. This allowed to start the real process of DEM production.

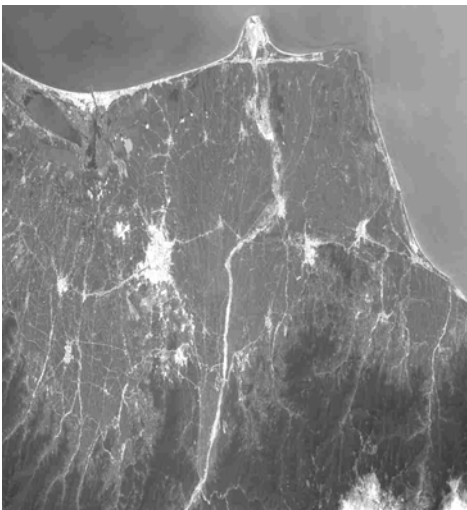


Figure2.1. Stretched source SPOT-5 stereo images (left image)

As source materials for production of the second DEM over the test area TK-350 satellite stereo images were used. After their scanning on UltraScan 5000 scanner the dynamic range of optical densities of images appeared to be about 256 grayscale levels.



Figure 2.2. Stretched source SPOT-5 stereo images (right image)

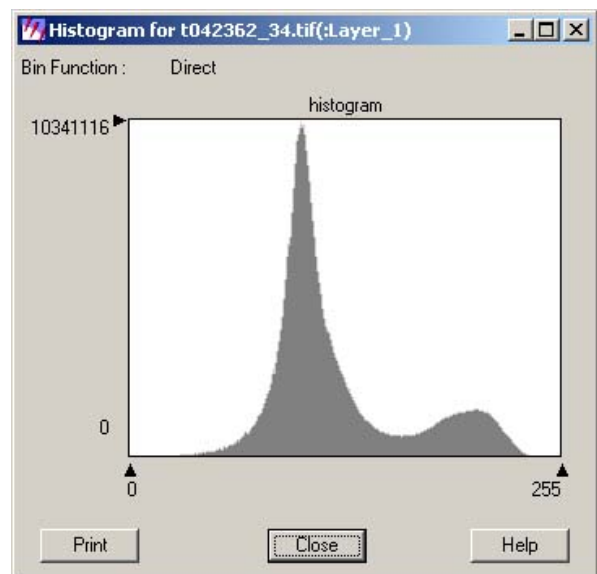
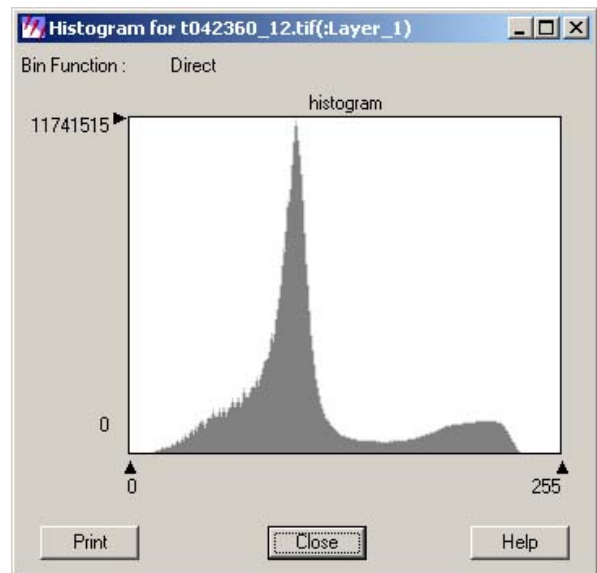


Figure 3. Histogram of source images of TK-350 stereo pair over Rasht, Iran

The outlook of scanned TK-350 satellite stereo images is shown on Figure .4.

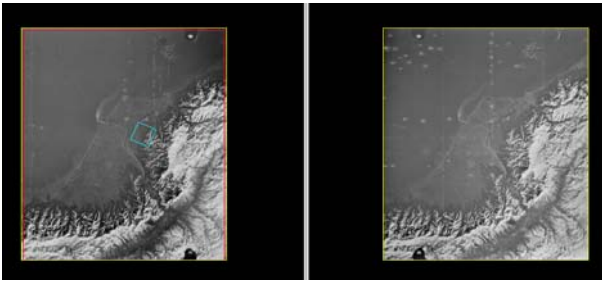


Figure 4. The outlook of scanned TK-350 satellite stereo images

As geodetic basis there were used 80 control points obtained from the provided maps (for orientation of SPOT-5 images) and 29 phototriangulation ground control points for TK-350 images. Both types of DEM were produced in UTM projection on WGS-84 ellipsoid using software technological modules of digital photogrammetric systems Z-Space v.2.0 (Institute of Information Technologies, Moscow, Russia) and Photomod v.3.6 (Racurs Company, Moscow, Russia). At first, on both digital systems there were produced computer versions of DEM in automatic mode using digital correlators. Then both versions of DEM were corrected by operators using software interfaces.

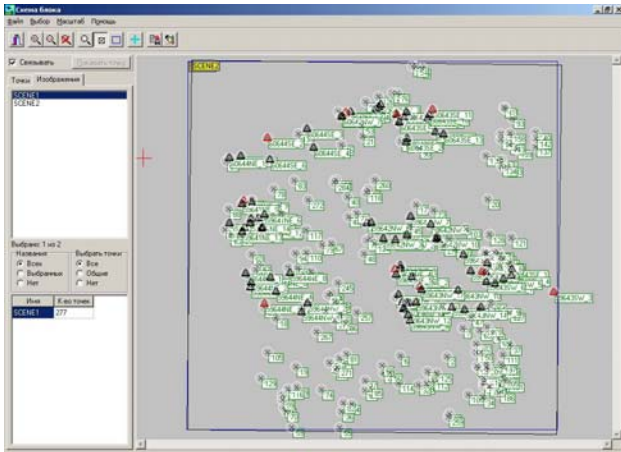


Figure 5. The relative location of the control points from maps in the block

3. DESCRIPTION OF DIGITAL PHOTOGRAMMETRIC SYSTEMS

System “Z-Space” is used for production of DEM and orthoimages from satellite stereo images TK-350. The system is constructed using modular principle. The following is a list of software modules as well as technological processes and functions implemented by them.

1. Project Manager – head module of the system

Process	Function
Project	Selection of name, creation of new project folder

	or opening (saving, copying) of an existing project
	Forming of project file and data files in appropriate formats on hard disk
	Input of project parameters in dialog or from files
	Creation and holding of imaging systems catalog
	Creation and holding of catalog of coordinate systems, ellipsoids and map projections
	Control of project state
	Setting of options of graphic elements display
	Conversion of raster and vector data
	Creation and holding of list of models for DEM construction
	Start of separate modules for current project

2. Orientation

Process	Function
Interior	Interior orientation of images
Relative	Relative orientation of images
Exterior	Exterior orientation of images

3. Rectification

Process	Function
Rectification	Epipolar rectification of images (fragments of stereo pair)
	Cutting of fragments of stereo pair

4. Production of DTM

Process	Function
MakeDTM	DTM production
EditDTM	Automatic editing of DTM

5. Stereo Editor

Process	Function
Stereo Editor	Browsing and editing of stereographic elements
	Manual editing of DTM

6. Orthophoto

Process	Function
Orthophoto	Orthophoto production

Separate modules of the system can be started through Manager or independently by Windows.

Architecture of digital system “Photomod” includes analogous technological modules and additional modules PHOTOMOD AT for construction and adjustment of phototriangulation. All the modules work under control of main shell of PHOTOMOD system Montage Desktop.

The main module PHOTOMOD DTM is used for production of DEM. The obtained computer variant of DEM is edited by operator in stereomode by separate and group correction of nodes and triangles of TIN model, by smoothing of contour lines and break lines, filtration of outbreaks, etc.

Module PHOTOMOD StereoDraw performs production and editing of vector layers in stereomode. A significant set of export/import vector formats is supported. Module PHOTOMOD StereoVectOr is used for display and editing of a map being updated in legend signs. The module has convenient two-monitor mode of work. Module PHOTOMOD Mosaic is used for production of fragments of orthoimages from satellite and aerial images and their mosaic. The functions of brightness adjustment provide seamless orthomosaic. It is possible to export it directly to MapInfo and ArcInfo cut into sheets or trapeziums of required size. The module PHOTOMOD ScanCorrect allows to use inexpensive polygraphic scanners after their accurate calibration.

4. ORIENTATION OF IMAGES IN GEODETIC SPACE

In order to construct geometric terrain model there were performed the required technological processes: interior orientation – to set parameters of connection of pixel coordinate system of digital images with commonly used photogrammetric image coordinate system and account of distortion of imaging system; relative orientation – for further production of free stereo model; exterior orientation – for production of geometric terrain model in geodetic space; production of epipolar images – for the process of automatic stereo matching of corresponding points on stereopair images. Production of terrain model in geodetic space using photogrammetric system PHOTOMOD from SPOT-5 images was done using RPC polynomials which are equations of connection between photogrammetric coordinates X,Y,Z and geodetic X,Y,Z.

As a result the following accuracy of construction of terrain model in geodetic space was achieved:

For SPOT-5 images

$RMS_{X,Y} = +/- 12.82$ m in plane;
 $RMS_H = +/- 7.0 - 15.3$ m in height

For TK-350 images

$RMS_{X,Y} = +/- 14.94$ m in plane;
 $RMS_H = +/- 8.58$ m in height

5. PRODUCTION OF DEM FOR THE TEST AREA

According to the plan of experiment production of DEM was done 15.32 km x 15.32 km in size with 40m spacing within the test area TS7 (Rasht, Iran) with the corner coordinates:

$49^{\circ}52'15.796'' - 50^{\circ}02'43.250''$ E
 $37^{\circ}04'16.443'' - 37^{\circ}12'27.858''$ N

The analysis of computer variant of DEM obtained using “Z-Space” system showed that in the flat part of test area there are a lot of relief “outbreaks” up to 40-50m in height. The mountainous part of DEM does not have such errors of determination of heights of terrain points. Due to this reason postprocessing of DEM included mainly the procedures of automatic smoothing of DEM using Grimson method within flat areas. The outlook of DEM corrected in such a way is shown on Figure 6.

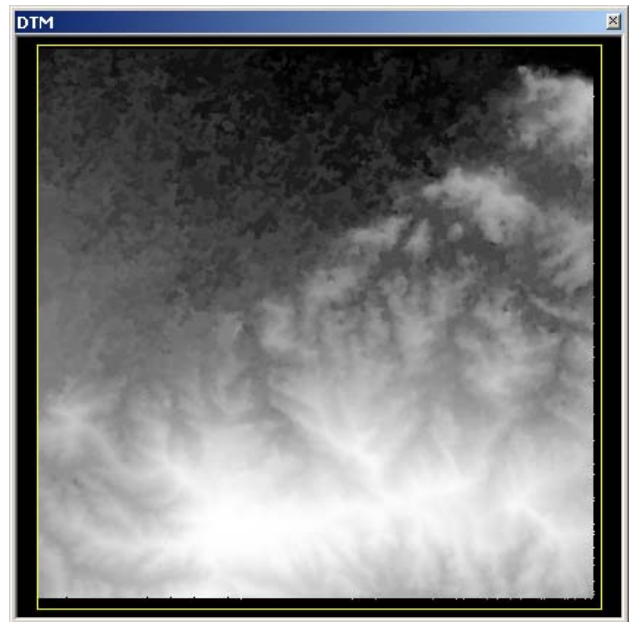


Figure 6. Outlook of DEM produced by “Z-Space” system from TK-350 images

The comparison of DEM produced from satellite TK-350 images with the test one showed the following accuracy characteristics:

$$RMS_H = +/- 14.1 \text{ m} \quad \Delta_H = 0.1\text{m}$$

The histogram of differences of their heights is shown below in Table 1.

Table 1

No.	Differences, m	Number of differences	%
1	0-5	51 810	36
2	5.1-10	38 029	28
3	10.1-15	25 647	18
4	15.1-20	15 613	9
5	20.1-25	8 128	5
6	25.1-30	4 697	2
7	30.1-35	2 167	1
8	35.1-40	566	0
9	40.1-45	237	0
10	45.1-50	13	0
11	50.1-55	7	0

The similar analysis of computer variant of DEM obtained using PHOTOMOD system showed absence of significant “outbreaks” (see Figure 7). This resulted in the histogram of differences of its heights with the heights of test DEM (Table 2).

Table 2

No.	Differences, m	Number of differences	%
1	0-5	53 264	37
2	5.1-10	38 142	28
3	10.1-15	23 370	17
4	15.1-20	15 526	9
5	20.1-25	9 539	4
6	25.1-30	5 017	3

7	30.1-35	1 008	1
8	35.1-40	566	0
9	40.1-45	237	0
10	45.1-50	13	0
11	50.1-55	7	0

The comparison of the DEM produced from SPOT-5 satellite images with the test one showed the following accuracy characteristics:

$$\text{RMS}_H = \pm 11.9 \text{ m} \quad \Delta_H = 0.0\text{m}$$

The outlook of the DEM produced from SPOT-5 images using photogrammetric system PHOTOMOD is shown on Figure 8.

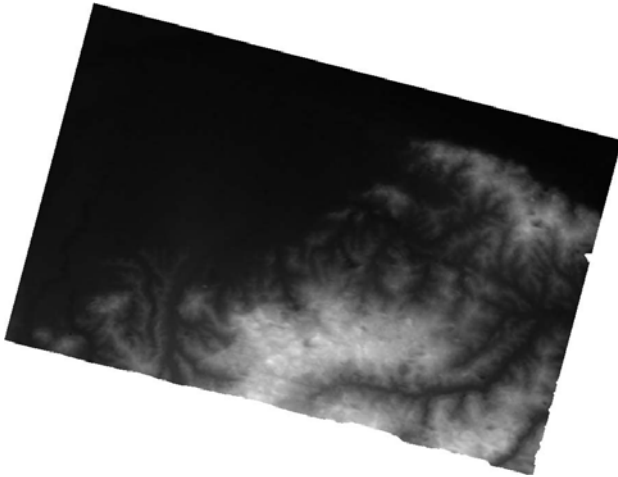


Figure 8. The outlook of the DEM produced from SPOT-5 images

6. CONCLUSION

The experiment performed in the frames of ISPRS allows to make a conclusion that satellite images SPOT-5 and TK-350 provide production of DEM of approximately one class:

$$\begin{aligned} \text{SPOT-5} & \quad \text{RMS}_H = \pm 10 - 14 \text{ m;} \\ \text{TK-350} & \quad \text{RMS}_H = \pm 12 - 16 \text{ m.} \end{aligned}$$