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ASSESSMENT ACCURACY OF THE TOPOGRAPHIC RASTER MAPS – IRAQ

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Introduction

The topographic maps that reflect the current state of area are indispensable for the successful development of any country. The majority of tasks in the field of economy and national economy requires for its solution the use of modern maps, which contain information on human settlements, economic and cultural facilities, roads, communications, borders and other countryside objects. However, to meet these requirements the topographic maps must be complete and precise that can be achieved by means of their regular update.

The current practice presupposes the update of the most important strategic and residential areas every 5–7 years, less important areas – every 10–15 years. One of the main ways of updating is carried out with the help of camera records [*politika.ru/about_articles/statya_obnovlenie_topograficheskih_kart.html*].

The topographic map update in many countries is conducted less significantly than it is required. Thus, Iraq is one of those countries, where nearly 95% of topographic maps at the scale of 1:25,000, 1:50,000 and 1:100,000 are not updated, and if they are, then only those with the small coverage areas. For example, the last update of 1:100,000-scale map of Iraq was in 1989 [*http://gcs.mowr.gov.iq/*]. The update of the road network maps gains its special importance, since 75% of transportation is carried out on the roads, and the road network is a constantly changing infrastructure [Gerke, 2006, *Grote, 2011*].

The purpose of this paper is to study existing maps, assessment of their geometric properties and analysis of the possibility to update these maps based on space satellite images of proper areas.

Problem Statement

This paper was written as part of solving the problem of updating the road network on raster topographic maps according to space satellites of earth surface.

The 1:100,000 scale maps of Iraq are available only in the raster format, and therefore the problem of replenishment and map updates in a bitmap representation is considered, without regard of vector conversion (time-consuming and expensive process). The use of the raster format for updating would reduce the cost of veridical and practically applicable maps.

The initial data for the solution of the problem are raster topographic maps of Iraq and space satellites of earth surface. Currently there are available raster topographic maps of Iraq of 1: 100000 scale, scanned with a resolution of 80 and 120 dpi.

Satellite images of earth surface are available on the Internet both on a paid basis and free of charge, the cost of images increases with their resolution

The main characteristic of satellite images is their spatial resolution. According to this characteristic the following are distinguished:

– satellite images of very low resolution of 10 000–100 000 m;
– satellite images of low resolution of 300–1000 m;
– satellite images of medium resolution of 50–200 m;
– space images of relatively high resolution of 20–40 m;
– satellite images of high resolution of 10–20 m;
– satellite images of very high resolution of 1–10 m;
– satellite images of ultrahigh resolution of less than 0,3–0,9 m.

In this case, images with a resolution of 0,3–40 m are considered high-resolution images.

Characteristics of satellite images obtained using different systems [Burshtinska et al., 2013, Gorshenin et al., 2013, Knizhnikov et al., 2004, Lyalko et al., 2006, *http://mapexpert.com.ua/index_ru.php?id=22&table=news*].

Evaluation objectives of the geometric properties of raster maps

Before the replenishment of raster maps it is required to evaluate the geometrical parameters in terms of correspondence with the further problem solving. On that basis, the first step should be conducted as the analysis of the geometric properties of raster maps.

The scale stability and the preservation of image contours similarity are considered to be the main geometric parameters of the topographic map.

If the scanned map does not have any geometric scale or angle distortions, the digital image is similar to its cartographic original.

Violations of the contours and size similarity can be caused either by deformation of the source of cartographic representation, or by violations that have emerged after scanning.

To determine and analyze the deviations of geometric properties of the map image we can use the illustration of kilometer coordinate grid by means of comparison with the coordinates of intersection of *X*- and *Y*-axis received on the bitmap with signed map coordinates. The relation of the orthogonal similarity of the mentioned values must be compiled in the case of absence of distortions.

For the analysis of the geometric properties of a raster map it is sufficient to investigate the parameters of the following transformations:

– Orthogonal transformation;
– Polynomial transformation of 1st, 2nd and 3rd order.

Determination of the geometrical properties of raster maps

The orthogonal transformation looks like the following: [*Chris, 2013*].

$$\begin{vmatrix} v_i^x \\ v_i^y \end{vmatrix} = \begin{vmatrix} a & b \\ -b & a \end{vmatrix} \begin{vmatrix} x_i \\ y_i \end{vmatrix} + \begin{vmatrix} c_1 \\ c_2 \end{vmatrix} - \begin{vmatrix} \overline{x}_i \\ \overline{y}_i \end{vmatrix}, \qquad (1)$$

where x_i, y_i – are the coordinates of i – the grid intersection received on the bitmap in pixels; $\overline{x}_i, \overline{y}_i$ – are the geodesic coordinates of corresponding grid lines; a, b, c_1, c_2 – are the transformation coefficients; v_i^x, v_i^y – the deviation at the point i that corresponds to X - and Y -axes.

Polynomial transformation of degree m at the point i is performed as follows:

$$\begin{vmatrix} x_i & y_i & \dots & y_i^m & 1 & 0 & 0 & 0 & \dots & 0 \\ 0 & 0 & 0 & \dots & 0 & x_i & y_i & \dots & y_i^m & 1 \end{vmatrix} \cdot \begin{vmatrix} a_1 \\ a_2 \\ \dots \\ a_q \\ b_1 \\ b_2 \\ \dots \\ b_q \end{vmatrix} - \begin{vmatrix} \overline{x}_i \\ \overline{y}_i \end{vmatrix} = \begin{vmatrix} v_i^x \\ v_i^y \end{vmatrix}, \qquad (2)$$

where $a_1, ..., a_q, b_1, ..., b_q$ – are the transformation coefficients; q – the number of polynomial members on degree m. The polynomial transformation in matrix form at the point i can be formulated in the following way:

$$V_i = H_i \cdot A - X_i, \ (i = 1...n), \qquad (3)$$

where V_i is the deviation vector at the point i; X_i – The vector of geodesic coordinates at the point i; A – The vector of the coefficients of polynomial transformation; H_i – The elements of matrix which can be calculated basing on the raster coordinates of the i -point; n – Number of points.

Vector A is computed by the least squares technique provided that:

$$\sum_1^n V_i^T V_i = \min. \qquad (4)$$

From the solution of the following equation system:

$$(\sum_{i=1}^n H_i^T \cdot H_i) \cdot A - \sum_{i=1}^n H_i^T \cdot X_i = 0, \qquad (5)$$

From which we receive the coefficients by the formula,

$$A = (\sum_{i=1}^n H_i^T \cdot H_i)^{-1} \cdot \sum_{i=1}^n H_i^T \cdot X_i \qquad (6)$$

Calculation of the orthogonal transformation and polynomial transformation coefficients of the first, second and third order has been carried out. To calculate the orthogonal transformation coefficients, the eq. (1) is transformed into:

$$\begin{vmatrix} x_i & y_i & 1 & 0 \\ y_i & -x_i & 0 & 1 \end{vmatrix} \cdot \begin{vmatrix} a \\ b \\ c_1 \\ c_2 \end{vmatrix} - \begin{vmatrix} \overline{x}_i \\ \overline{y}_i \end{vmatrix} = \begin{vmatrix} v_i^x \\ v_i^y \end{vmatrix}. \qquad (7)$$

Assessment of the geometrical properties of raster maps of the various Iraq cities

We have chosen for the assessment several raster topographic maps of Iraq cities. Characteristics of the assessed maps are given in Table 1. The cities chosen for estimation are located in various parts of the country. For the construction of topographic maps in Iraq there was adopted a system of UTM (Universal Transverse Mercator), developed by engineers of the US Army in the 1940 [*http://gcs.mowr.gov.iq/*]. Fig. 1 shows a map of Iraq with the cities which maps were evaluated marked on it.

Table 1

Properties of the evaluated maps

NO:	Name of city	Nomenclature, Coordinates of South-West Angle: Lat. Lon	Maps are Scanned with Resolution dpi	Difference of Scale A/B	Last Update	Scale of Aerial Photographs in the Latest Update
1	Sulaimaniya	I – 38 – D – NW 35° 30′, 45° 00′	120	1,004106	1989	–
2	Um – Rehel	H – 38 – C – SE 31° 00′, 44° 30′	120	0,995880	1985	1:10000
3	Thari	I – 38 – A – NW 35° 30′, 42° 00′	80	0,999625	1986	1:130000
4	Shuaib – Farach	H – 38 – I – NW 30° 30′, 44° 00′	80	0,993588	1986	1:50000
5	Rumaila	H – 38 – L – SW 30° 00′, 47° 00′	120	0,995585	1988	1:25000
6	Chamchamal	I – 38 – C – NE 35° 30′, 44° 30′	120	0,997245	1989	1:50000
7	Basrah	H – 38 – L – SE 30° 00′, 47° 30′	120	0,993263	1989	130000
8	Samawa	H – 38 – D – SW 310 00′, 450 00′	80	0,993953	1989	1:80000
9	Nasiriya	H – 38 – E – SW 310 00′, 460 00′	80	0,999178	1989	1:80000
10	Medaynah	H – 38 – L – NW 300 30′, 470 00′	120	0,993156	1985	1:200000

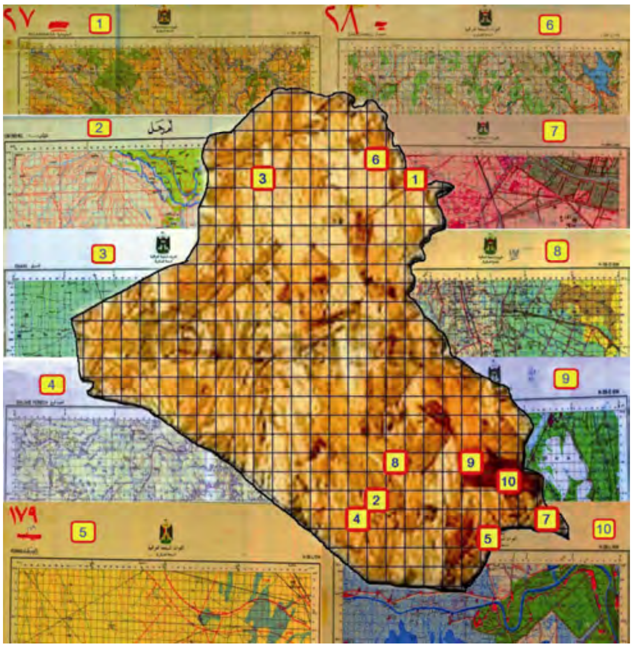

Fig. 1. The map of Iraq with city marks [http://gcs.mowr.gov.iq/]

110 characteristic points have been chosen on the raster image of each map. These points are the "crosses" of a kilometer coordinate grid. The chosen points are evenly distributed on 55 control and 55 check points for calculation of the above-described transformations, and for the calculation control. The transformation coefficients have been calculated in terms of the control point coordinates, and the deviations have been analyzed basing on the check point coordinates. The mean value of X - and Y-axes deviation has been calculated for each of the specified transformations. The X axis deviation for the reference points is calculated from the formula:

$$s_x^o = \frac{\sum_{i=1}^{n} v_i^x}{n-q}, \qquad (8)$$

where s_x^o – the mean value of X -axis for the control points; X -axes deviation for the check points is calculated from the following formula:

$$s_x^k = \frac{\sum_{i=1}^{n} v_i^x}{n} \qquad (9)$$

where s_x^k – the mean value of X -axis deviation for the check points.

Y -axes deviations are calculated in the similar way. The deviation output is given in table 2.

Irregular deviations of the axes indicate that scales difference is small and is within the accuracy of a graphics map, it does not exceed 0.3 mm in the map scale.

The use of polynomial transformations of the second and third degrees lead to somewhat smaller deviations on the crosses grid (see. Table 2) than in the orthogonal and affine, however these differences are much smaller than graphic accuracy of a shout-hin map and can be ignored.

Table 2

Deviation value of various transformations

Transformation	Mean Deviation of X, m		Mean Deviation of Y, m	
	Control Points, s_x^o Max/Min (average)	Check Points, s_x^k Max/Min (average)	Control Points, s_y^o Max/Min (average)	Check Points, s_y^k Max/Min (average)
Orthogonal	12,7/8,5 (10,5)	13,0/8,4 (10,6)	13,9/6,1 (9,8)	13,1/6,7 (10,1)
Polynomial of the 1st Order (Affine)	12,7/8,4 (10,4)	13,0/8,4 (10,5)	13,7/6,1 (9,8)	13,0/6,6 (9,9)
Polynomial of the 2nd Order	10,2/5,1 (8,5)	11,5/5,1 (9,1)	8,7/4,8 (7,1)	9,4/5,3 (7,2)
Polynomial of the 3rd Order	9,2/4,8 (7,6)	9,9/4,8 (8,2)	8,0/4,8 (6,4)	8,9/4,8 (6,7)

Polynomial transformation coefficients of the first order (affine transformation) allow us to analyze scale change on each axis. For this purpose it is necessary to conduct the scale ellipsis construction. Scale of the X - and Y -axis is calculated as:

$$\left. \begin{aligned} m_x &= \sqrt{a_1^2 + b_1^2}, \\ m_y &= \sqrt{a_2^2 + b_2^2} \end{aligned} \right\}, \qquad (10)$$

where m_x, m_y – the scales of X and Y -axis, accordingly, and a_1, a_2, b_1, b_2 – the transformation coefficients, eq. (2).

To estimate the axes-difference at affine transformation maximum and minimum scales (the magnitudes of long A semi-axis and short B semi-axis of scale ellipsis), were determined [Serapinas, 2005].

On the basis of the conducted calculations and scale ellipsis construction we have stated that maximal-ratio A/B is 1.004106 (map of Sulaimaniya), minimal ratio is 0.993156 (map of Medaynah), average scale ratio is 0.9965579. Scale ellipsis with semi-axis A and B are mostly circle approximate, which indicates the absence of essential distortions on a map.

The possibility of using satellite images to update raster topographic maps

Despite the graphical accuracy of the maps installed in the calculations, there is a significant disadvantage of a low-resolution scan of maps available. Scanning with a resolution of 80 and 120 dpi results in raster maps with pixel size of 0.3 mm and 0.2 mm, respectively. Error values during scanning are shown in table 3.

Table 3

Errors introduced during scanning of different scales maps depending on the resolution

Map Scale Resolution	1:25000	1:50000	1:100000
80 dpi	7,5 m	15 m	30 m
120 dpi	5 m	10 m	20 m

Such significant errors in the general case require map re-scan with a resolution of at least 300 dpi. However, in our case the possibility of maps re-scans is not present, so it is necessary to update the existing maps with low resolution. Hence, high resolution satellite images, for example, SPOT, can be used for upgrade, there is no need for images of very high and ultrahigh resolution. The use of images with a resolution of 5m will allow with the appropriate precision to upgrade maps of scale 1: 25000, 1: 50000, 1: 100000 images with a resolution of 15 m – 1: 50000, 1: 100000, images with a resolution of 30m – 1: 100000. Given the nature of the terrain of the Republic of Iraq (a large part is occupied by deserts), even the accuracy of up to 30 m is permissible.

Conclusions

The investigation has been provided with the assessment of the accuracy of raster topographic maps. It has been established that given the scale deviations of maps does not exceed 0.2 mm, which corresponds to the graphic accuracy of maps. Different-scale has an equal distribution which means that the map correction can be conducted with help of adjustments. Thus, the maps do not contain any considerable geometrical distortions that makes it possible to use them for the analysis and representation of the road network changes on the satellite high-definition images.

It is also shown that the resolution when scanning of maps is insufficient, in terms of accuracy it is necessary to perform scanning with a resolution of 300 dpi (preferably – 600 dpi). For existing maps it is enough to use satellite imagery with a resolution of 5 to 30 m.

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Оцінка точності топографічних растрових карт Іраку

Р. Абдаллах

Поставлено завдання можливого оновлення та поповнення растрових топографічних карт. Ірак є однією з тих країн, де близько 95 % топографічних карт з масштабом 1: 25000, 1: 50000 та 1: 100000 не оновлюються, а якщо і оновлюються, то тільки карти з малим охопленням територій.

Оценка точности топографических растровых карт Ирака

Р. Абдаллах

Поставлена задача возможного обновления и пополнения растровых топографических карт. Ирак является одной из тех стран, где около 95 % топографических карт с масштабом 1:25000, 1:50000 и 1:100000 не обновляются, а если и обновляются, то только карты с малым охватом территорий.

Assessment accuracy of the topographic raster maps – Iraq

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This article is concerned with the task of possible update and completion of raster topographic maps. Iraq is one of those countries, where nearly 95 % of topographic maps at the scale of 1:25,000, 1:50,000 and 1:100,000 are not updated, and if they are, then only those with the small coverage areas.