
PECULIAR FEATURES AND PROBLEMS OF VISUAL INTERPRETATION OF DIGITAL SPACE IMAGES

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ABSTRACT

The investigation deals with the specific properties of object recognition upon discrete space images which practical using is intensively developed. This paper studied the following problems: influence of analog-to-digital (A/D) conversion on representation and interpretation properties of discrete space images; psychophysiological aspects of objects recognition upon discrete space images; peculiar features of aerospace generalisation of discrete images; specific properties of stereoscopic visual observation of discrete aerospace images.

The following principal results were obtained. Influence of parameters of scanning (size of aperture and value of sampling rate) on representation and interpretation properties of discrete space images was established. Notion of integrate object of recognition which is consisted of finite quantity of image pixels was determined. Statement of optimal aerospace generalisation and cartographic specifications for produced discrete images were defined. The relationship between resolution of stereoscopic visual perception and pixel size of discrete space images was estimated. Generality of information procedures between visual perception and mapping interpretation of discrete space images was shown.

1 INTRODUCTION

At present, practical using of digital (discrete) space images is intensively developed. The investigation deals with the specific properties of object recognition upon discrete space images. This paper studied the following problems: influence of analog-to-digital (A/D) conversion on representation and interpretation properties of discrete space images; psychophysiological aspects of objects recognition upon discrete space images; peculiar features of aerospace generalisation of discrete images; specific properties of stereoscopic visual observation of discrete aerospace images.

2 INFLUENCE OF ANALOG-TO-DIGITAL (A/D) CONVERSION ON REPRESENTATION AND INTERPRETATION PROPERTIES OF DISCRETE SPACE IMAGES

2.1 Theoretical estimation of the discrete space images representation properties

One type of discrete images is received by surveying space scanner, and other type is formed from analog-to-digital (A/D) conversion. Russia has considerable fund of high quality analogue space images, so A/D conversion is basic way to receive discrete images for computer-based mapping. This way is realized thanks to office photogrammetric scanners.

The transformation from continuous (photo) images to discrete ones is connected with the degradation of initial image quality, which is evaluated in resolving power and photographic contrasts decrease. Consequence of this transformation is the losing of some part of cartographic information. The formal estimation of cartographic information losing may be based on proposed method.

The resolving power of the transformed discrete image (R^d) can be estimated as:

$$R^d = 1/2(2p_k^2)^{0.5} \tag{1}$$

or

$$R^d = 1/2(p_k^2 + p_{k1}^2)^{0.5}, \tag{2}$$

p_k è p_{k1} - sizes of the discrete image pixel, mm.

Formula (1) was proposed in (Szangolies, 1987), and the second one was studied in (Knizhnikov, Zinchuk, 1998).

These equations are correct under such conditions as:

$(2p_k^2)^{0.5} \geq 1/2R^{in}$ - for formula (1),

$(p_k^2 + p_{k1}^2)^{0.5} \geq 1/2R^{in}$ - for formula (2),

R^{in} - resolving power of the initial image, mm⁻¹.

A/D conversion is also connected with the decrease of the photographic contrasts. This transformation is determined from parameters of the office photogrammetric scanners (b and d). Its combined influence may be estimated with modulation transfer function (MTF):

$$T(R) = \prod_{i=1}^n T_i(R), \tag{3}$$

$T_i(R)$ - modulation transfer function from the i -scanner's parameter.

MTF from scanning aperture (b) was proposed in (Frieser, 1975):

$$T_1(R) = \sin(\pi Rb) / \pi Rb, \tag{4}$$

R - resolving power of the initial image.

The effect of the scanning aperture size is shown in figure 1.

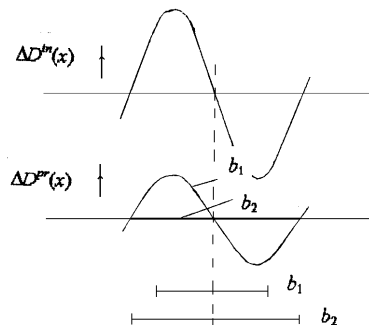


Figure 1. Modulation of an initial photographic contrasts under different size scanning apertures (b_1 and b_2): $\Delta D^{in}(x)$ - photographic contrast of initial space image; $\Delta D^{pr}(x)$ - photographic contrast of produced space image

We have proposed that MTF from sampling rate (d) is an analog of the MTF from scanning aperture, so:

$$T_2(R) = \sin(\pi Rd) / \pi Rd, \tag{5}$$

R - resolving power of the initial image.

So, the combined influence from b - d parameters may be estimated with equation:

$$T(R) = T_1(R) T_2(R) = \sin(\pi Rb) / \pi Rb \sin(\pi Rd) / \pi Rd. \tag{6}$$

2.2 Experimental estimation of the discrete space images representation properties

Experimental estimation of the proposed equation (formula 6) consisted of:

- A/D conversion of the photographic test objects which photographic densities were measured;
- determination of the relationship between produced digital test objects luminance and initial image test ones photographic (blackening) density;
- microphotometry of the linear photographic test objects, characterized by a different resolving power, and calculation of their initial photographic contrasts;
- A/D conversion of the photographic linear test objects under given scanning aperture and sampling rate sizes (b and d) and photographic densities analogs determination of the produced digital linear test ones.

A relationship between discrete test objects luminance l (in gray levels from 0 to 255) and their photographic density D^d has been established as result of the first and the second experiment stages. Plot of this relationship is shown in figure 2.

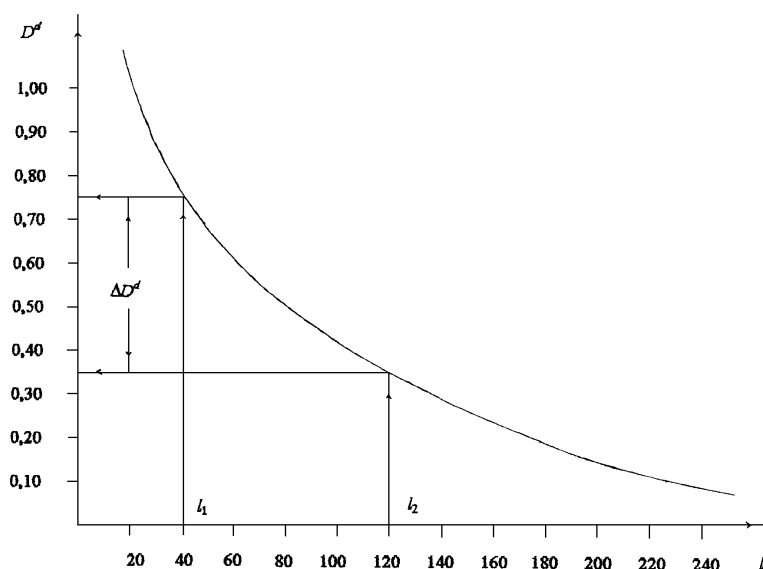


Figure 2. Plot of the relationship between discrete test objects luminance l and their photographic density D^d

Then initial photographic contrasts ΔD^{in} have been calculated under the different resolving power (R) in agreement with formula 4 (table 1). These calculations were made due to scanning plots of the linear photographic test objects.

Resolving power of the linear test objects R, mm^{-1}	Photographic contrasts of the linear test objects			Values of the modulation transfer function	
	Initial image ΔD^{in}	Discrete image		Theoretical $T(R)$	Empirical $T_{em}(R)$
		Theoretical values ΔD^d	Empirical values ΔD_{em}^d		
25	0,82	0,73	0,69	0,89	0,84
30	0,73	0,61	0,58	0,84	0,79
35	0,57	0,45	0,42	0,79	0,74
40	0,43	0,32	0,28	0,74	0,65
45	0,34	0,23	0,21	0,68	0,62
50	0,25	0,15	0,14	0,61	0,56

Table 1. Representation properties of the initial and discrete (digital) linear photographic test objects

An analogous characteristics of the produced digital linear test objects ΔD^d have been obtained under 0,0075 mm scanning aperture and 0,0075 mm sampling rate. Theoretical contrasts ΔD_i^d have been calculated as:

$$\Delta D_i^d = \Delta D_i^{in} \cdot T(R_i), \tag{7}$$

R_i - resolving power of the linear photographic test objects ($R_i = 25, 30, 35, 40, 45, 50 \text{ mm}^{-1}$). Empirical contrasts $\Delta D_{em i}^d$ have been obtained due to relationship, which is shown in figure 2.

Empirical values of the modulation transfer function $T_{em}(R_i)$ have been calculated as:

$$T_{em}(R_i) = \Delta D_{em i}^d / \Delta D_i^{in} \quad (8)$$

The experimental data obtained (table 1) show that divergence between theoretical contrasts ΔD^d and empirical ones ΔD_{em}^d is equal to 0,02-0,04 Bel. This result confirms the correctness of suggested equation (formula 6) for estimation of discrete space images representation properties. The relationship described allows studying the influence of the A/D conversion on the cartographic interpretation truth (completeness). This one was used for 1:25 000 topographic map updating based on space images interpretation.

2.3 Estimation of the A/D conversion influence on the cartographic interpretation quality

Topographic objects mapping quality may be obtained due to cartographic interpretation truth criteria. Cartographic interpretation truth (or completeness) is determined as weighted average probability of mapped objects recognition from space images Q , which proposed in (Bezhic et al., 1993):

$$Q = \sum_{i=1}^n P(N_i) \cdot P(M_i), \quad (9)$$

$P(N_i)$ - probability of i -type's topographic objects true recognition from space images (each type includes such object's group as relief objects, hydrography, road set, vegetation and others); $P(M_i)$ - a relative frequency of i -type objects

occurrence upon created map contents; n - a number of topographic object's types; $\sum_{i=1}^n P(M_i) = 1,0$.

Extensive statistical investigations have allowed to calculate the values of $P(N_i)$ under 45 mm^{-1} resolving power space images recognition and the parameters of $P(M_i)$ for 1:25 000 topographic map (Bezhic et al., 1993).

A/D conversion causes a decrease of mapped objects recognition probability under discrete image interpretation $P(N_i)_d$ that calculated according to (Zhivichin, Sokolov, 1980):

$$P(N_i)_d = P(N_i) \Delta D_i^{in} / \Delta D^d \quad (10)$$

This relationship transforms in agreement with formula (8) as:

$$P(N_i)_d = P(N_i)^{MT(R)} \quad (11)$$

Mapped objects recognition probabilities were established due to interpretation of the 45 mm^{-1} resolving power discrete space image, which produced under 0,0075 mm scanning aperture and 0,0075 mm sampling rate. Then weighted average probabilities were calculated using formula (9) for continuous Q and discrete Q_d space images interpretation.

Comparative estimation of Q and Q_d values shows that A/D conversion of the continuous (photo) images characterized by the 45 mm^{-1} resolving power under 0,0075 mm scanning aperture and 0,0075 mm sampling rate produces to the losing upon the average 10 per cents of the initial cartographic information. It is necessary to take account of this information loss in agreement with specific properties of the discrete space images visual interpretation (Knizhnikov, 1997).

3 PSYCHOPHYSIOLOGICAL ASPECTS OF OBJECT RECOGNITION UPON DISCRETE SPACE IMAGES

A starting point at research of interpretation properties of different types of space images is the understanding of psychophysiological aspects of object recognition (Knizhnikov, 1997), so it is necessary to evaluate peculiar features of visual perception of the discrete (digital) space images. Correctness of interpretation of discrete images depends on quantity of pixels forming this image. This research is studied quantity of pixel indispensable for the sure interpretation of constructions in a small city, a settlement of an agricultural type and a settlement of a cottage type (on three discrete space images accordingly).

Digitized space photoimages, obtained by KVR-1000 on scale 1 : 220 000, were used as basic materials for experimental interpretation. The digitization was made on a complex of INTERGRAF. The original images were scanned by the aperture 10 microns of the square form, and then were visualized. According to the formula (2) resolving power of these images was calculated as 35 mm^{-1} , and sizes of pixels on terrain - 3 m.

On this research stage a possibility of interpretation was estimated on an example of images, which are formed by finite number of pixels. Such images are interpreted as integratedly perceived objects. This feature is formulated in gestaltpsychology (from a german word Gestalt - integrated object, integrated form). Integratedly perceived images have no an inside structure, but their forms are visually perceived as a unit.

Ten separate constructions were random selected on each of three images. These constructions have minimum area, but sure recognized. The number of pixels, which were compounding the area of interpreted constructions, is listed in table 2. The mean area of objects has compounded 20 pixels (piece of an image - 4 x 5 pixels). The mean area was calculated to better than 6,5 % accuracy.

Number of object	Area of interpreted objects, pixels		
	Small city	Settlement of an agricultural type	Settlement of a cottage type
1	19	20	20
2	21	22	20
3	19	17	16
4	17	20	19
5	17	23	21
6	20	21	21
7	22	18	16
8	23	20	20
9	17	19	17
10	21	17	20
Mean area, pixels	20	20	20
Calculated accuracy of mean area, % (pixels)	± 6,5 (± 1)	± 6,0 (± 1)	± 6,0 (± 1)

Table 2. Mean area of interpreted objects

According to the formula (2) diagonals of the area of interpreted objects has compounded approximately five-multiple value of the resolution of discrete space images. The following this relationship is necessary for sure interpretation of integratedly perceived objects on discrete space images of defined level of generalization.

4 PECULIAR FEATURES OF AEROSPACE GENERALISATION OF DISCRETE IMAGES

4.1 Generalization levels of space images

Generalization is the cartographic term, but at present, aerospace generalization is indispensable for optimization of representation and interpretation properties of discrete space images. The modern space images contain the geoinformation of many levels (Kravtsova, 1988). These levels are defined as geoinformation levels or levels of geoimages (Berliant, 1996).

Quantity of geoinformation levels depends on complexity of an outline of an investigated category of objects, and also capabilities of images to transmit the information on objects of these levels. For example, the settlements on images can be shown at three levels: level of small-sized constructions inside habitation quarters (figure 3a); level of large buildings describing a plan of habitation quarters (figure 3b); level of habitation quarters in settlements (figure 3c).

Object of researches can be the objects as one, and several geoinformation levels, and for each level usage of images of an optimum level of a generalization is expedient. Features of visual perception of objects on discrete images condition last position.

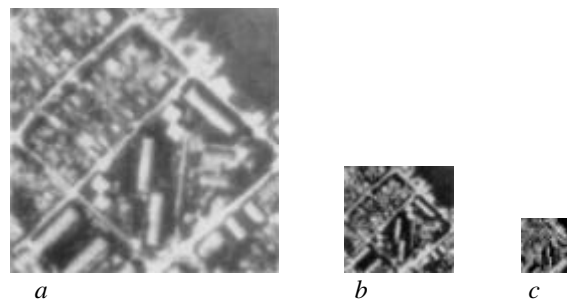


Figure 3. Discrete space images of optimal generalization levels: a) level of small-sized constructions inside habitation quarters; b) level of large buildings describing a plan of habitation quarters; c) level of habitation quarters in settlements

The optimum visual perception of objects is reached on produced discrete images with calculated representational properties (formulas 2 and 6). It can be shown on an example of discrete images, which produced for the purposes of a topographic interpretation.

4.2 Aerospace generalization for topographic interpretation

Now, usage of space photographic images for compiling or updating of the large-scale topographic maps (1:10 000, 1:25 000, 1:50 000) considerably extends. This process can be provided by usage of photographic images obtained by the KVR-1000. The representational properties of these images allow to receive copies at 20-multiple increase of the originals up to a scale 1:10 000. The images of such scale contain the objects even of small-sized constructions, imaged on a map of the same scale.

As it was marked above, it is the first geoinformation level of images. However, according to the norms for updating a map to scale 1:25 000 the available information will be exuberant. According to the norms, the separate large constitutions describing a plan structure in habitation quarters are shown on the topographic maps of the given scale. That is second and more generalized geoinformation level of objects.

Habitation quarters of cities are shown on the topographic maps of a scale 1:50 000. In a considered example it is most general — the third level of the geoinformation about settlements, for which one the information of initial images is considerably excessive. So discrete images with optimum level of a generalization are produced for interpretation of objects of a settlement.

The parameters of discretizing (sizes of scanning aperture and sampling rate) were calculated to supply the relationship between the size of a pixel and geometrical average size of interpreted objects (section 3). At this approach the conventional scheme of surveying in different scales is modeled, at which one the representational properties of surveying systems provide a different values of the resolution on terrain and photographic contrasts of original images (figure 4).



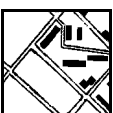
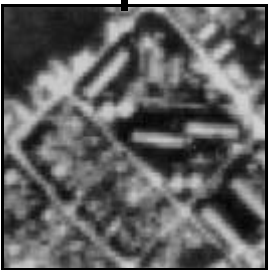





Levels of geoinformation	Generalization of discrete space images on scales			Scheme of interpretation
	1 : 10 000	1 : 25 000	1 : 50 000	
	<p>Level 1 (small-sized constructions inside habitation quarters)</p> 			
<p>Level 2 (large buildings describing a plan of habitation quarters)</p> 				
<p>Level 3 (habitation quarters in settlements)</p> 				

Figure 4. Generalization of discrete space images for obtaining the information of the definite level

The produced discrete images were obtained by scanning of initial space photographs on a complex of INTERGRAPH and by using of the software package PHOTOSHOP. The initial image of a settlement (small city) is obtained by KVR-1000 and is increased up to a scale 1:10 000 (resolving power of the increased image — 2 mm^{-1}).

The parameters of scanning were established for obtaining the information of the first geoinformation level with allowance for of geometrical average sizes of constitutions in the given settlement (10 x 15 m), showed on the topographic map of a scale 1:10 000, and also with allowance for of representational properties of an initial image. According to the formula (2) sizes of a pixel of a produced discrete image have compounded 0,18 x 0,18 mm (figure 4 — the first geoinformation level), that provides the spatial resolution of a discrete image of 2,5 m. According to calculated pixel size the initial image was digitized under aperture of 0,18 mm and of 0,18 mm. The value of the modulation transfer function (MTF) for the images of interpreted objects of the given geoinformation level at optimum parameters has compounded 0,97 (formula 6). The decrease of photographic contrasts has not exceeded 3 %.

The digitizing parameters were calculated for extraction of the information of the second geoinformation level with allowance for of geometrical mean sizes of large buildings (20 x 70 m) describing a plan of habitation quarters of settlement. The sizes of the pixel of produced discrete image have compounded 0,72 x 0,72 mm (figure 4 — the second geoinformation level), that provides the spatial resolution of a discrete image of 10 m. Further by programmatic way the obtained image was adduced to a scale of a updated map (1:25 000), thus the obtained image was visually accepted as continuous. The value of MTF for the images of interpreted objects of the given geoinformation level at optimum parameters has compounded 0,90. The decrease of photographic contrasts has not exceeded 10 %.

The scanning parameters were established for obtaining the information of the third geoinformation level with allowance for of mean sizes of habitation quarters in settlement (100 x 150 m). The sizes of the pixel of produced discrete image have compounded 1,8 x 1,8 mm (figure 4 — the third geoinformation level), that provides the spatial resolution of a discrete image of 25 m. The obtained image was adduced to a scale of an updated map (1:50 000), thus the obtained image was visually accepted as continuous. The value of MTF for the images of interpreted objects of the given geoinformation level at optimum parameters has compounded 0,97. The decrease of photographic contrasts has not exceeded 3 %.

The analysis of the results of discrete images interpretation, introduced in figure 4, has shown, that they respond the norms of the topographic mapping of the defined scales. The optimum level of a generalization of produced discrete space images is determined on the basis of obtained relationship between sizes of a pixel and geometrical mean size of interpreted objects (section 3), and also by calculation of representational and photometric parameters of produced image (formulas 2 and 6).

5 SPECIFIC PROPERTIES OF STEREOSCOPIC VISUAL OBSERVATION OF DISCRETE AEROSPACE IMAGES

The qualitative information on the spatial form of interpreted objects is traditionally received on a stereoscopic pair of photographic (analogue) images. It is known that the person accepts the depth of three-dimensional space due to a lot of features, which ones are founded on activity of physiological and psychological mechanisms of a visual system. The greatest value for stereophotogrammetry and interpretation have the kinesthetic mechanism of a convergence indicated by D. Berclly in 1709, and mechanism of binocular disparity established by C. Witston in 1839, which one has opened an artificial stereoscopic effect and has invented the stereoscope.

5.1 Geometrical fundamentals of forming of a stereoscopic image

In modern psychology of visual perception there are two basic approaches to explanation of a phenomenon of stereoscopic vision. One of them esteems a plastic of a spatial image of observed object as reacting to stimulant, which one is the binocular parallax; at the other approach it is considered, that the person directly accepts the information on relative arrangement of observed points. It is known that the first approach is adopted in a photogrammetry.

Binocular parallax $\Delta\gamma_i = \gamma_M - \gamma_C$ of two different points of space (C and M) and range difference up to these points ΔL_i are connected by following base relation of a stereoscopy:

$$\Delta L_i \approx \frac{L^2}{b_{op}} \cdot \Delta \gamma_i , \quad (12)$$

L - spacing interval up to observed points; b_{op} - ophthalmic basis.

In a limiting case the same relation binds a threshold of stereoscopic perception of depth (ΔL) and sharpness of stereoscopic vision (v_s), i.e.

$$\Delta L \approx \frac{L^2}{b_{op}} \cdot v_s . \quad (13)$$

The quality and detail of a spatial image of observed object, which one is formed by a visual system of the person, is determined by a sharpness of stereovision. Geometrically it is characterized along an ophthalmic axis by a threshold of perception of depth (ΔL), and in perpendicular direction to an ophthalmic axis - linear value of sharpness of stereovision (ΔL_o), i.e.

$$\Delta L_o = Lv_s . \quad (14)$$

From the formula (13) and (14) follows, that observation without increase may be estimated as

$$\Delta L = \frac{L}{b_{op}} \cdot \Delta L_o . \quad (15)$$

The relation (15) allows to proceed from direct observation of objects in a nature to the analysis of their discrete stereomodels.

5.2 Properties of discrete stereomodels

It is known, that basic parameter of representational properties of a single *analogue* image is its resolution, which one corresponds to the size of minimum object, separately recognized on a image. For single *discrete* image the value of the resolution (pix) estimates differently (Knizhnikov, Zinchuk, 1998):

$$pix = (pix_c^2 + pix_{cl}^2)^{0.5} , \quad (16)$$

pix_c and pix_{cl} - sizes of the parties of a pixel on a discrete image*, mm.

However in both cases the indicated parameter characterizes the size of a minimum informative element of an image. At natural observations the minimum size of recognizable spatial object is determined by linear value of a sharpness of stereovision ΔL_o . Enabling numerical equaling of detail of visible object (ΔL_o) and its discrete image (pix), and also determining the size of a threshold of stereoscopic perception of depth of discrete images (ΔL_g) at according to the formula (15), as

$$\Delta L_g = \frac{L}{b_{op}} \cdot pix , \quad (17)$$

we have received

$$\Delta L_g = \frac{L}{b_{op}} \cdot (pix_c^2 + pix_{cl}^2)^{0.5} . \quad (18)$$

* Pixel of a discrete image is defined as a pixel received at analogue-digital conversion of the initial optical or photographic image.

The quantitative value of L_g characterizes quality of discrete stereomodel formed in visual centers of a brain.

It is known that the representational properties of images are traditionally estimated on special photographic test-objects. In practice of researches the different kinds of photographic test-objects are applied (Frieser, 1975), thus all their known types are intended for an estimation of single image quality. The estimation of plastic of stereomodels demands producing and usage of spatial test-objects. Certainly, it is desirable, that the form of spatial test-objects is corresponded to the forms of a relief of a surface or other three-dimensional objects of terrain, and their texture - figure of the landscape features on images.

The stereo test-objects consisting of triplet of stereoscopically conjugated images were designed and produced for an estimation of quality of discrete stereomodels and its changes which characterized by value of a threshold of perception of spatial depth and the size of a pixel of discrete images of a stereo pair. At construction of stereo test-objects the results of researches (Knizhnikov, 1967) were allowed, and the formation of triplets is implemented according to a method (Knizhnikov, 1997), ensuring simultaneous observation by the person of two stereomodels - reference and investigated. As a result of developments six elementary stereo test-objects (figures 5a-5f) as gnomonic projection of a truncated cone obtained from two points of view - of the left-hand and right-hand eye were produced thus the right-hand discrete picture is formed by pixels of the different sizes (accordingly, 0,3; 0,6; 0,9; 1,2; 1,5; 1,8 mm).

The experiments on stereo test-objects with elementary form and texture have confirmed that the offered method is suitable for an estimation of influencing of the size of a pixel on quality of stereomodel. The comparative estimation of the left-hand (analogue) and right-hand (discrete) test stereomodels demonstrates that increase of the size of pixel results in a decrease of quality of an accepted stereoscopic effect. This process is accompanied also by geometrical transformations of discrete stereomodel - in our case by its flattening. The detected feature can be quantitatively characterized by the introducing of a *flattening coefficient* of stereomodel which one is equal g_L ($0 \leq g_L \leq 1$), i.e.

$$g_L = \frac{\Delta L}{\Delta L_g} = \frac{\Delta L_i}{pix}, \quad (19)$$

ΔL and ΔL_g - values of a threshold of stereoscopic perception of spatial depth of stereomodels formed on analogue and discrete images, accordingly.

With allowance for formula (19) formula (17) will be converted as:

$$\Delta L_g = \frac{L^2}{b_{op}} \cdot \frac{\Delta L_o}{g_L}. \quad (20)$$

For a stereo pair of discrete images produced by pixels of the square form with defined size (pix_c), the coefficient of flattening (g_L) can be calculated as $g_L \approx 0,7 \cdot \Delta L_i / pix_c$ in relation to analogue stereomodel with the ΔL_i -resolution.

Formula (20) was used for estimation of properties of stereomodel observed on discrete aerospace images. It is known, that the value of a threshold of perception of spatial depth of a stereo pair of images with allowance for of factor of increase of an observation system (v), altitude (L) and basis (B) of surveying is calculated under the formula (Sciridov, 1959):

$$\Delta L = \frac{L^2}{Bv} \cdot v_s. \quad (21)$$

At observation of images with increase (v) linear value of a sharpness of stereovision is calculated as $\Delta L_o = Lv_s/v$, so with allowance for of formulas (15)- (18) formula (21) for stereo pairs of discrete images can be shown, as

$$\Delta L_g = \frac{L}{B} \cdot (pix_c^2 + pix_{cl}^2)^{0,5}, \quad (22)$$

or (with allowance for of formula 20)

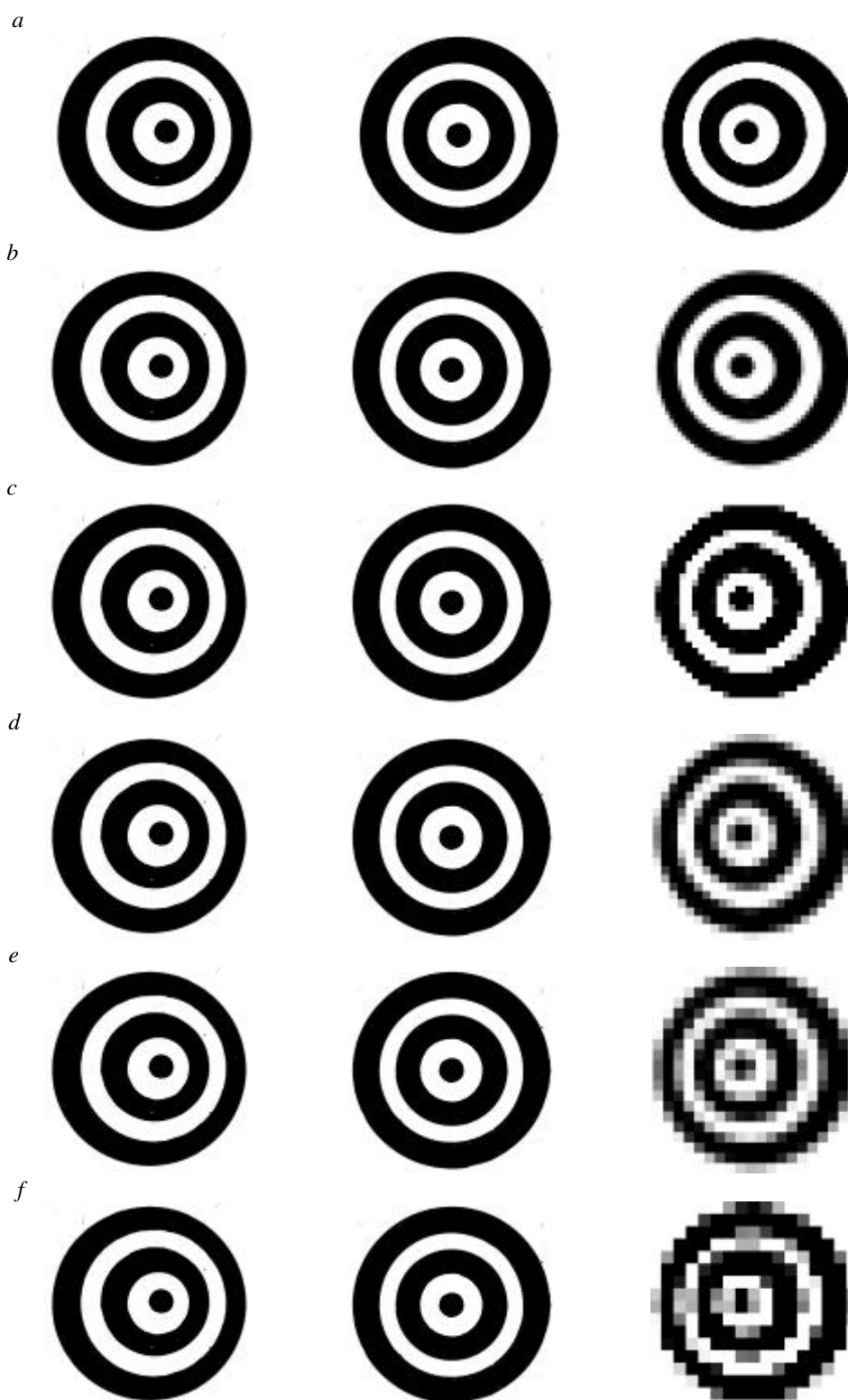


Figure 5. The stereo test-objects - double stereo pairs of a test-object (truncated cone), which are formed by pixels of the different size: a) 0,3 mm; b) 0,6 mm; c) 0,9 mm; d) 1,2 mm; e) 1,5 mm; f) 1,8 mm

$$\Delta L_g = \frac{L}{B} \cdot \frac{\Delta L_o}{g_L}. \quad (23)$$

Usage of relation (23) will allow to calculate (a priori) value of a threshold of stereoscopic perception of spatial depth on a stereo pair of discrete images, which ones will be obtained as a result of analogue-digital conversion, and to estimate properties of observed stereomodel. Under the formula (22) it is possible to receive an a posteriori estimation.

5.3 Experimental interpretation of a forest on discrete aerophotoimages

The capabilities of extraction of the spatial information on discrete stereoimages were reviewed on an example of the digitized aerophotos of a scale 1:1500, obtained by the AFA-BA-40 from an altitude $L = 600$ m and basis $B = 60$ m. The stereo pairs of discrete aerial photographs obtained by scanning of initial images on a complex of INTERGRAPH and by using of the software package PHOTOSHOP are shown in figure 6.

Three stereo pairs of discrete images were produced from pixels of the square form by the size 0,3, 0,9 and 1,8 mm. According to the formula (16) resolution of discrete images, reduced to the sizes on terrain, have compounded - 0,8, 2,5 and 5,1 m (produced images were added to a scale 1:2000 for convenience of researches). Secondary aspen and birch forest by an altitude of 28-30 m is shown on obtained discrete images. Some young arbors by an altitude of 8-10 m grow to east from house.

The stereo pair of discrete images, for which one a threshold of stereoscopic perception of depth (L_g), reduced to the sizes on terrain, makes 8,4 m (formula 22), is shown in figure 6a. The given stereo pair allows confidently interpreting three levels on an altitude: a herbaceous cover, group of young arbors, adult forest. The threshold of stereoscopic perception of depth of the second stereo pair (figure 6b) is equal 25,5 m on terrain. The stereomodel flattens out, and only two altitude levels - herbaceous cover and an adult forest are stereoscopically differed on these images. The threshold of stereoscopic perception of depth for the third stereo pair (figure 6c) is so great (50,9 m), that the discrete stereomodel becomes actually flat.

The results of stereoscopic recognition of different altitude forest elements, which are shown on three stereo pairs of discrete aerial photographs (figure 6), demonstrate, that the offered relation (22) allows to estimate a stereomodel of discrete images, sufficiently for prediction of its possibilities for interpretation of investigated objects, and also for definition of quality of the spatial information about studied geographic objects.

Many categories of geographic objects are differed on a relative altitude. The settlements, forest, relief and others are concerned to such objects. For interpretation of available altitude differences it is necessary to forecast and to estimate properties of stereomodels observed on discrete images, which ones are particular formed by analogue-digital conversion of continuous (photographic) images. With usage of offered relations (22) and (23), it is possible to calculate the sizes of pixels, and, therefore, parameters of scanning (size of the aperture and sampling rate), which ones provide the sure interpretation of available altitude differences.

6 CONCLUSIONS

Analog-to-digital (A/D) conversion is one of the basic ways to receive discrete space images for computer-based mapping. It is shown that A/D conversion of the continuous (photo) images produces to the losing upon not less than 10 per cents of the initial cartographic information. It is necessary to take account of this information loss in agreement with specific properties of visual interpretation of the discrete space images.

Notion of integrate object of recognition which is consisted of finite quantity of image pixels was determined. Such objects are interpreted as integratedly perceived images. This feature is formulated in gestaltpsychology (from a German word Gestalt - integrated object, integrated form). Integratedly perceived images have no an inside structure, but their forms are visually perceived as a unit. Diagonal of the area of integratedly interpreted object has compounded approximately five-multiple value of the resolution of discrete space images. The following this relationship is necessary for sure interpretation of integratedly perceived objects on discrete space images of defined level of generalization.

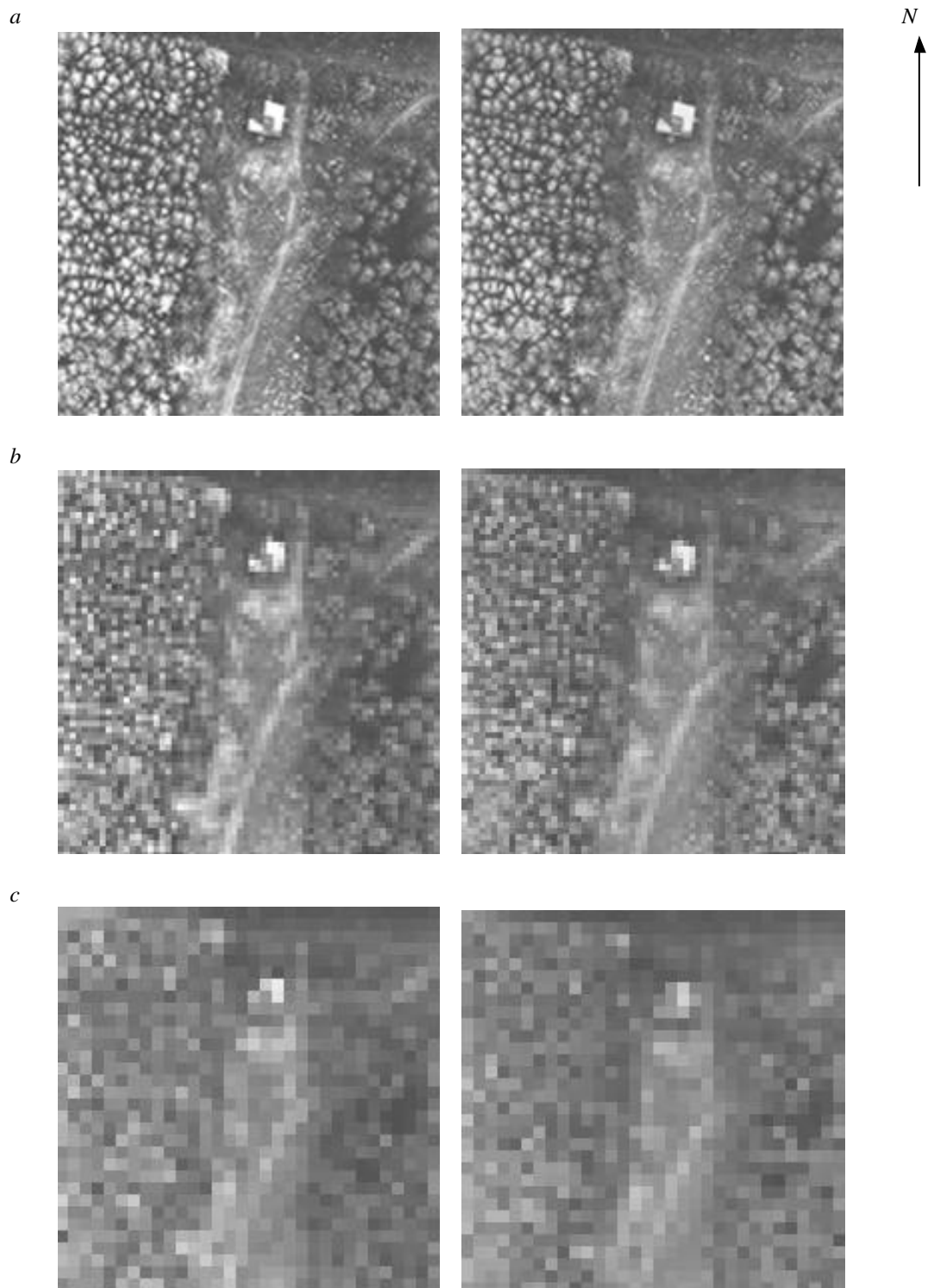


Figure 6. Stereo pairs of discrete aerophotos of a forest formed with the different resolution:
a) 0,8 m; b) 2,5 m; c) 5,1 m

Statement of optimal aerospace generalisation and cartographic specifications for produced discrete images were defined. The optimum level of a generalization of produced discrete space images is determined on the basis of obtained relationship between sizes of a pixel and geometrical mean size of interpreted objects, and also by calculation of representational and photometric parameters of produced discrete image.

The relationship between resolution of stereoscopic visual perception and pixel size of discrete space images was estimated. The value of a threshold of stereoscopic perception of spatial depth, which one characterizes the quality of discrete stereomodels, is directly proportional to the size of a pixel of discrete images of a stereo pair. The stereo test-object consisting of triplet of stereoscopically conjugated images was designed and produced for an estimation of quality of discrete stereomodels and its changes which characterized by value of a threshold of perception of spatial depth and the size of a pixel of discrete images of a stereo pair. *Flattening coefficient* of stereomodel was introduced for estimation of discrete stereomodels. The results of experimental stereoscopic recognition of different altitude forest elements, which are shown on three stereo pairs of discrete aerial photographs, demonstrate that the offered relations allow to estimate possibilities of interpretation of investigated geographic objects.

The analysis of listed conclusions has allowed to reveal the generality of information procedures between visual perception and mapping interpretation of discrete aerospace images.

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REFERENCES

- Berliant A., 1996. *Geoiconics*. Astreia, Moscow.
- Bezhic S. et al., 1993. Interpretational potentialities of space photos used for 1:25 000 topographic map updating. *Geodesy and Cartography*, N 12, pp. 31-33.
- Fisher H., 1975. *Photographic information recording*. The Focal Press, London and New York.
- Knizhnikov Yu., 1967. Some data about accuracy of a stereoscopic observation. *Bulletin of high schools. Geodesy and airphotography*. Vol. 2, pp. 77-83.
- Knizhnikov Yu., 1997. *Aerospace sensing. Methodology, concepts, problems*. Moscow State University Press, Moscow.
- Knizhnikov Yu., Zinchuk N., 1998. Peculiar features of visual interpretation of discrete space images. *Geodesy and Cartography*, N 11, pp. 15-22.
- Kravtsova V., 1988. The concept of unified fund of space images and new parameters for their geographic and cartographic estimation. *Bulletin of Moscow State University. Geography*, N 5, pp. 53-62.
- Sciridov A., 1959. *Stereophotogrammetry*. Geodesic Literature Press, Moscow.
- Szangolies K., 1987. Zum Auflösungsvermögen von Fernerkundungssystemen - Stellungnahme zum Beitrag "Elektronische und optoelektronische Methoden der Fernerkundung". *Vermessungstechnik*, N 3, s. 96.
- Zhivichin A., Sokolov V., 1980. *Photographic images interpretation*. Nedra, Moscow.