ON DIGITAL MAPS QUALITY

Vladimir I.Kaminsky
"Rosgeoinform" Centre
Russia

Abstract

The report presents the concept of digital maps (DM) quality, states the mathematical models of quality estimation and also efficiency of used methods. Also presented are fundamental tenets of the DM quality control system.

1 Introduction

Production of digital maps has been lately developed in Russia. A fund of digital maps on a 1:1000 000 scale for the territory of Russia has been created with participation of six geoinformation centres for two years and work is being continued on 1:200 000 scale map digitizing which shall be completed within the next few years in accordance with the "Advanced Production Processes of Russian Federation Cartographo-geodetic Support" federal program.

The basic property of digital maps is their quality. Most attention has been concentrated on this problem in developing data processing methods and production practices of DM. As a result of long-term studies and taking into consideration the known experience, the digital maps quality concept has been stated and a quality control system has been developed and realized in practice [1,2].

2 Digital maps quality concept

In developing this concept we proceeded from the quality definition given in the ISO Standard - "set of properties and characteristics of products, which provides meeting the specified or assumed demands" [3].

The basic requirement to the digital maps is as follows: in contents,accuracy and reliability, the digital maps shall correspond to the cartographic sources used for their creation.

Besides:

* The digital maps shall meet the requirements of the standard and also shall not rank below the best analogs in their characteristics.

* The high quality of the DM is achieved by observance of the specified degree of accuracy of accomplishment of production processes.

* The digital maps quality is a developing notion since it shall at all times take into account diversity and evolution of requirements of various users to the digital data on terrain.

* The cost of DM shall depend on their quality and shall meet the effective demand of buyers.

The process of development of their content, production practices and also the edition work being carried on exert to a large extent effect on the digital maps quality.

2.1 Requirements to quality control

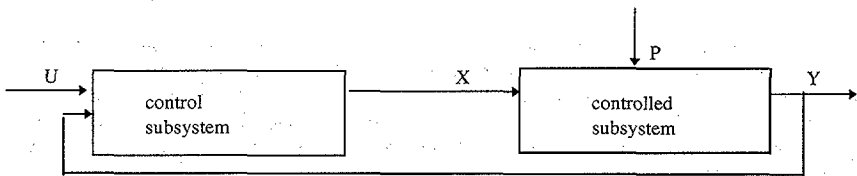The digital maps quality control layout may be represented as

Figure 1: DM Quality Control Layout
U - specified DM quality; X - control action;
Y - functioning result, i.e. digital map of par-
ticular quality; P - interference caused by dif-
ference of Y from U

It is evident that provision of specified quality presumes fulfilment of the Y = U condition. To minimize e = Y - U, two ways are possible:

* Creation of ideal conditions for production of digital maps, at which P $\rightarrow$ 0 (disturbance control). In actual practice this cannot be provided due to the impact of a variety of factors: errors of the attending personnel, inadequate accuracy and reliability of hardware, expansion of the circle of users and because of this, change of requirements to the DM, etc.

* Realization of such X = X(U,Y), at which e(X) $\rightarrow$ 0 with minimum delay, i.e. control action is required to be generated for recovering the digital maps quality with presence of interference P $\neq$ 0 (deflection control).

In the general case, quality control shall include: determination of the required level of the digital maps quality, i.e. preparation and solution of U; determination of control action X for realization of adopted solution; check of Y state and timely action on P.

2.2 Quality indexes

In compliance with State Standard GOST 15467-79, product quality control (estimation) is "a set of operations including selection of quality indexes range of the product to be estimated, determination of magnitudes of these indexes and their comparison with the base ones" [4].Consequently, the digital maps control procedure shall consist of three stages:

* Selection of quality indexes, their base values and methods of determination.

* Obtaining the quality indexes values and their processing.

* Making decisions.

Objectivity of the digital maps estimation depends on the proper selection of quality indexes. The selection of indexes assumes representation of multidimensional space of quality characteristics to the reduced dimensionality space for convenience of their analysis and routine monitoring. In developing the quality indexes their information content serves as one of the basic prerequisites,i.e. the ability to present essential information on the DM from the point of view of target application.

In connection with this such an index as reliability of digital information on terrain that can be expressed quantitatively in terms of no-error probability should be highlighted. In addition to the above,other indexes should also be considered essential: adequacy of structural-and-analytical representation of information to the methods of its processing and use; redundancy in representation of intermediate and output digital cartographic information, etc. These indexes are assigned in design.

It is known that errors originating in production of digital maps exert an effect on their quality. The effect of errors as a whole can be represented as $Q = \sum_{i=1}^{s} T_i \, p_i$, where p_i - probability of i - type error occurrence, T_i - weight of i - type error, s - number of error types.

Practical use of Q makes it possible to arrange them by collected statistical data on error origin, and use (or develop) respective control methods, introduce changes into the production process

2.3 Estimation of quality control effectiveness

In developing the digital maps quality control methods it is important to know their effectiveness, i.e. to estimate the quality of the control procedure itself. Let the function of losses in control have the form

$$f(r,r_*) = \begin{cases} 0 \text{ with } r=r_* \text{ , no error;} \\ c_1 \text{ with } r>r_* \text{ ,type I error (false alarm);} \\ c_2 \text{ with } r<r_* \text{ , type II error (false safety)} \end{cases}$$

where r - sign of acceptability of parameter under control ($r=0$ with $y \in N$, $r=1$ with $y \notin N$; $r_*=0$ with $y_* \in N_*$, $r_* =1$ with $y_* \notin N$); c_1 and c_2 -"cost" of losses of types I and II errors; y - parameter under control; N - range of allowed values; * - index used to designate the obtained data.

Then the control reliability will be $p_0 = p(r = r_*)$ and error probability - $p_1= p(r>r_*)$, $p_2= p(r<r_*)$. The average risk that is to be minimized may be considered as quality lose.

$$\Delta L = M\{f(r,r_*)\} = \sum_{i=0}^{2} c_i \, p_i = c_1 \, p_1 + c_2 \, p_2$$

where M - expectation operator.

For digital map $c_1 \ll c_2$; $p_1 \rightarrow 0$

$$y_* \in i=1,2, \dots , s; \ \Delta L = \sum_{i=1}^{s} \ T_{2i} \ p_{2i}$$

The use of priori probabilities of II-type errors for the control methods being worked out makes it possible to perform computation of their effect on the average risk. In this case, the losses for the digital maps user caused by the II-type i-th error can be attributed to the weight of T_i of the given error. The form of function $T_{2i} = f(T_i)$ depends on the field of application of DM and nature of tasks being solved by their aid. The values of p_{2i} can be finally determined by the results of the use of control methods.

This concept is used as a basis of the digital maps quality control system.

3   Digital maps quality control system

By the digital maps quality control system is meant such a system that is intended above all to guard against error occurrence. This means that the basic accent in attainment of the required quality of digital maps is extended from control of finished digital maps to the accuracy of observance of production processes.

To introduce this system in production of digital maps, it is necessary to:

* Take into account the general level of the production process, i.e. its complexity.

* Take into account the extent of professional training of personnel.

* Organize clear-cut interaction of specialists (sections).

* Form a group responsible for quality control including representatives of main process sections.

* Provide stimulation of high-quality work.

The digital maps quality control group performs the following functions:

* Checks the materials having cartographic data.

* Analyses users' claims to the DM and works out recommendations for keeping close track of these claims.

* Periodically checks control means and methods for their efficiency and meeting promising requirements of potential DM users.

* Analyses the results of tests of methods and production processes of DM made on the basis of other production practices.

* Draws up programs for improvement of digital maps quality.

In the quality control system, the prominent role is played by the information aids.

3.1 Information aids

Information aids (IA) include data on quality indexes, factors effecting it, and also the used control methods. Therewith the following requirements are placed on the IA: provision of quality control efficiency; achievement of specified reliability, completeness and optimal periodicity of information receipt; efficient "coverage" of production processes by control operations; preparation of recommendations on selection and use of most effective means for collection, processing, transmission and storage of digital data on terrain.

In their function the information aids may be both internal and external.

Working out of internal information aids is connected with the development of a data base reflecting the state of the production process from the point of view of observance of the required quality of digital maps being produced. The external information aids are concerned with organization of data and its passage outside the computer. They include documents, developed and classified in detail for all levels of specialists participating in creation of DM, on the quality of digital maps specifying the work and execution of records for each production process in accordance with particular quality indexes.

3.2 Quality control

The digital maps are checked for quality by the aid of organizational-and-production measures aimed at detection of errors in production processes and products.

For the checking procedure and requirements to the DM quality control, refer to the respective standard documents and instruction manuals.

Inspection organization layout used at geoinformation centres makes provision for:

* Input check of cartographic sources for completeness and correctness of terrain data representation.

* Check of map preparation for digitizing (correctness of selection of objects according to location and semantics, entering data into the digital maps log, use of additional cartographic and reference materials, etc.).

* Check of maps for proper digitizing (precision of object metrics and semantics, observance of production process requirements, topologic analysis, etc.).

* Check of digital maps for proper formation in the storage or transmission-to-user format.

* Acceptance of finished digital maps at the quality control department.

The required quality of digital maps is achieved by the use of advanced program control and detected error correction facilities.

4   Conclusion

The basic points stated in this report of the and relating to the concept of digital maps quality and the quality control system used in practice illustrate those views and that tool which provide creation of digital maps in present-day Russia at the up-to-date requirements level of geoinformation science.

References

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