Optimization of hydrographic studies using geochronological tracking

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Abstract. Information technology and geochronological tracking have been widely used in retrospective studies of the specific use of knowledge-based and expensive navigation-hydrographic equipment. The results of such studies serve the basis for support services, logistics supply schemes, support networks, etc. Today the feasibility of such studies is especially relevant for the items of active-autonomous navigation and hydrographic equipment. The competitive state of the domestic precision marine instrumentation industry objectively requires a systematic approach to study the demand and application of the above items. It is the geochronological tracking toolkit that may become the basis of a new marketing approach to planning the promotion of items of active-autonomous navigation and hydrographic equipment to the Russian and international market for marine and river transport services. This paper considers qualitatively new capabilities of the above-mentioned tools, as well as the rationalization of the corresponding algorithmic apparatus.

1. Introduction

The results of retrospective studies of the use of samples of modern knowledge-intensive and expensive equipment of various types are the basis for developing solutions for logistics distribution plans and their optimization, amount of attracted funds, amount of necessary financing, etc. This thesis is fully applicable to the items of domestic active-autonomous navigation and hydrographic equipment. Taken together the constructive growth of the complexity of modern request-response navigation equipment, principles and algorithms for processing relevant signals, approaches to illumination of the navigation at sea require further development of methods and forms of logistical support for the technical readiness of this type of products, as well as the introduction of new methods into practice for ensuring such readiness.

Scientific and methodological toolkit of geochronological tracking has found the widest application in retrospective studies of the application of various objects, products and artifacts, which is shown in works [1–5]. The geochronological tracking made it possible to develop a procedure for testing research hypotheses concerning stable trends in the processes of object movements, the use of surveillance tools, traffic control, etc. Today, this geochronological tracking is used to analyze modern delivery networks, optimize traffic, dispatch systems, etc. Its mathematical implication comes down to
the search and evaluation of the statistical significance of the isomorphism of the corresponding graphs: the final graph of geochronological tracking is presented as a graph-basis in the structure of which the subgraph isomorphic to the given one is revealed, i.e. the presence of a one-to-one display of one graph on the subgraph of another is established, in which the incident ratio is maintained. A graph that is isomorphic, to which a subgraph is determined in the base graph of geochronological tracking, topologically describes one or another definite hypothesis of research about a stable application feature. Next, the degree of stability is determined in recognizing the hypothesis of the study on the detected peculiarity in movements using the statistical apparatus of confidence probability and confidence intervals [6–7].

The modern appearance of systems and products of active-autonomous navigation and hydrographic equipment is determined by the specifics of the technical implementation of the main tasks of monitoring the navigation situation and probing the driving environment. The modern stage of development of active-autonomous navigation-hydrographic equipment for its traditional forms of implementation (transponder beacons, automated navigation systems, global positioning stations, etc.) is characterized by the following:

- achievement of a certain limit in the development of the capabilities of modern systems of active-autonomous navigation and hydrographic equipment focused on self-autonomous application. The potential of such complexes, determined primarily by the aperture of the main antennas, has reached a theoretical maximum, and even the appearance of conformal antennas having range advantages in a certain sector of angles does not fundamentally solve the problem of increasing the above range [8–11];
- focus on the network-centric approach in the organization of lighting of the situation, providing not only for the receipt of situation data from individual objects of active-autonomous navigation and hydrographic equipment, but also from elements of remote infrastructure (i.e. radio hydroacoustic buoys, rapidly deployable lighting elements, unmanned undersea vehicles, etc.), as well as by receiving and using information from stationary and positional systems for collecting data on the marine situation when entering the area of their operation. With this approach, any vessel may be an information center combining all the information available in the area of operations on the navigation situation, exposing additional elements (external emitters, probes, etc.) if necessary, and using this information in solving tasks. The alternative may be to collect and process information from the onshore situation center, followed by the transmission of integrated information to consumers, each of whom becomes the owner of not only the information that he observes directly, but also that observed by other elements of the network in the observer’s area of operations [12–15];
- extensive use of active-autonomous navigation-hydrographic equipment of both new generations of materials and components (materials, sensors, microelectronic base, etc.) and the next generation of application software focused not only on signal processing, but also on the use of calculated models for the use of active means, expert systems for supporting decision making, interpretation of the exposed object situation using digital mapping data sets, etc. [16–20].

At the same time, the analysis of works [6–11] shows that modern instrument making for marine industry is increasingly oriented towards the increase of the efficiency of creation and application of products of active-autonomous navigation-hydrographic equipment due to consideration of positive results of their previous use, minimization of their weight and size characteristics, with preservation or increase of probing and signal-transmitting potential. This fact introduced new classes of tasks in retrospective studies of the use of items of this type of equipment. The use and stationary placement of expensive objects of active-autonomous navigation and hydrographic equipment today is based on the results of a detailed study of various placement options. It is this fact that determines the relevance of the application of various geographic information methods and technologies for studying trends in the spatial distribution of applied processes, and in particular, the method and software-methodological tools of geochronological tracking.
2. Materials and Methods
The above summarized description of the modern stage of domestic active-autonomous navigation and hydrographic equipment allows concluding on the progressive increase in the complexity of the created and developed products of this type of monitoring and surveillance devices, on the objective increase in their cost and measures of responsibility of operators for reasonable and effective placement in the geospace, timely provision of their technical readiness for use as intended.

In the process of algorithmization of geochronological tracking techniques described in [1, 3] a single rational procedure for checking the statistical stability of embedding isomorphic hypothesis subgraphs into a basic graph-track was developed and improved. The features of this geochronological tracking procedure are largely determined by the effectiveness and accuracy of its use in applied research of this type of equipment based on geographic information systems. It is evident that the high computational and temporal complexity of the basic algorithm for determining the isomorphic embedding in a graph poses high requirements to correct algorithm-program implementation of this procedure in practice. The initial architectonics of the algorithm for implementing the procedure for statistical verification of hypotheses for active-autonomous navigation and hydrographic equipment based on geochronological tracking was not optimal, as shown in the block diagram notation in Fig. 1.

This fact determined the need to specify the appropriate optimization problem of the specified algorithm. Such an optimization problem was set and solved. The solution of the above optimization problem was reduced to the definition of some invariant of calculated computability, resource economy and accuracy. This made it possible to consider the algorithm associated with such an invariant optimal in the system of selected summary indicators of the algorithm computational performance. The described optimization, in a pragmatic aspect, makes it possible to expand the applicability of the mathematical apparatus for statistical testing of hypotheses of the use of hydroacoustic technology based on geochronological tracking for a wide variety of aspects of modern marine instrument making: production logistics, analytical planning and new areas of its study.

The objectively described optimization was expressed in a significant simplification and harmonization of the general architectonics of the algorithm for implementing the procedure for statistical verification of hypotheses for active-autonomous navigation and hydrographic equipment based on geochronological tracking. The final view of this optimized algorithm is given in the block diagram notation in Fig. 2.

Ultimately, the described optimization made it possible to provide variability in the best possible application of the algorithm for testing statistical hypotheses based on geochronological tracking for various combinations of input data and accuracy requirements, resource intensity and speed of the algorithm for output data. In turn, this contributed to the widespread introduction and automation of geochronological tracking, as an applied method of retrospective studies of the use of active-autonomous navigation and hydrographic equipment.

3. Results
The optimization of the given algorithm of retrospective geoinformational studies of active-autonomous navigation and hydrographic equipment on the basis of scientific and methodological apparatus of geochronological tracking ensures the increase of efficiency and accuracy of its application during evaluation of efficiency of deployment of objects, antenna fields, accompanying telecommunication networks, etc. in geographical space. It is obvious that further steps of improving the algorithm for testing hypotheses of retrospective research based on geochronological tracking are associated with identifying and structuring classes of invariants that simplify the procedure for searching and ordering the corresponding isomorphic attachments-hypotheses in the graph-basis of the geochronological track of applications of products of active-autonomous navigation and hydrographic equipment.
Figure 1. Algorithm for statistical testing of hypotheses of application of navigation-hydrographic equipment items based on geochronological tracking.
Figure 2. Structure of optimized algorithm for statistical testing of hypotheses of application of navigation and hydrographic equipment product based on geochronological tracking

In this case, the boundary conditions for obtaining solutions to the corresponding optimization problems will always be defined as the boundaries of a set of real numbers with a set of algebraic and logic-functional actions assigned over it.

The prospects of further work on improving the scientific and methodological tools of geochronological tracking and the corresponding geoinformation algorithms are closely linked with the use of artificial intelligence tools for big data analysis. In this case, we refer to such technologies as: soft computing, expert systems, fuzzy logic systems, Data Mining, Big Data and others [16–20]. This perspective makes it possible to expect further expansion of the field of practical use of the
geochronological tracking apparatus in software tools for supporting design and technical solutions based on the analysis of the facts of application of relevant products of navigation and hydrographic equipment.

4. Discussion
The new quality of interaction between marine instrument-making enterprises and relevant consumers in the operation of products of active-autonomous navigation and hydrographic equipment is determined by the need to meet the objective demand of modern society for an effective information infrastructure for monitoring and controlling the navigation situation in the waters of inland reservoirs, seas and the World Ocean. Besides, it should be possible to quickly receive and fully exchange data on the current and retrospective state of products of active-autonomous navigation and hydrographic equipment in electronic format between all participants of the considered process.

5. Conclusion
This new quality is expressed in the form of new possibilities for generating data on the course of operation and application for the purpose of products of active-autonomous navigation and hydrographic equipment based on geochronological tracking, which may become the basis of a new marketing approach to planning the promotion of domestic marine navigation equipment products to the Russian and international market. The modern practice of operation and application of expensive objects of marine and highly complex instrumentation urgently needs these capabilities among developers, manufacturers and operators of active-autonomous navigation and hydrographic equipment.

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