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DIGITAL METHODS FOR UNERRORIC OF THE ONBOARD LOCATOR OPERATOR WORK QUALITY CONTROL

ADELIYA BUROVA[1], ALEXANDER SHEMYAKOV[2], ANDREY SOROKIN[3]
[1,2,3]Moscow Aviation Institute (National Research University), Moscow, Russian FederationK
E-mail: [1]adeliya_yu_burova@mail.ru, [2]a.o.shemyakov@mail.ru, [3]sorokin_mai@mail.ru

ABSTRACT

The questions connected with research of additional possibility of estimation automation of the onboard locator operator means' work results directly onboard are considered. The aim of the study is to develop the concept and methodology of hardware-software support of multilevel quality control of the operator of onboard locating means in the training mode of their functioning onboard the ship. During the study, methods of hardware-software modeling of deductive algorithms for digital signal processing were used. The proposed and developed principles and digital methods of multilevel quality control of such work in the training mode of operation of onboard locating means are described. The structural scheme of multilevel evaluation of the results of training of the operator of these tools during their functioning in the training mode is given.

Keywords: *Hardware-Software, Onboard Locating Means, Multilevel Quality Control, Training Results Evaluation, Training Mode, Digital Signal Processing.*

1. INTRODUCTION

The level of danger, to which the dry-cargo ship from Hong Kong was exposed when colliding with the submarine in the Pacific Ocean on February 8, 2021, actualized the research of additional possibility of hardware-software support of multilevel quality control of operator's work on onboard locating means (OLM) of commercial and also passenger ships [1, 2]. Digital methods and electronic devices of error reduction of automatic estimation for results of training of OLM in a training mode of their functioning onboard a vessel can and should provide possibility of multilevel control of work quality of this operator directly on his workplace, instead of only on shore simulators [3, 4].

Recurrent methods of deductive processing of digital signals make it possible to do so when implementing computational algorithms for evaluation of OLM operator's performance on programmable logic integrated circuits (PLIC) and digital signal processors [5, 6]. For hardware-software support of its multilevel quality control it is necessary and sufficient to use PLIC that are part of OLM hardware [7, 8].

2. METHODOLOGY

The aim of the study is to develop the concept and methodology of hardware-software support of multilevel quality control of OLM operator's work in the training mode of their functioning onboard the ship [9, 10]. This goal is due to the problem of choosing hardware and software tools for the prevention of such control.

To achieve the stated goal, the following tasks were set and solved:

- system analysis of multilevel algorithms for digital processing of measurement and control results;
- comparative analysis of recurrent algorithms for deductive processing of digital signals.

The methods of hardware-software modeling of deductive algorithms of digital signal processing (DSP) were used during the research.

The theoretical basis for the development of the proposed concept and methodology of hardware-software support of multilevel quality control of OLM operator in the training mode of their operation onboard a ship can and should be considered unerroric deductive processing of digital signals based on multilevel discrete Fourier transform (DFT) of complex signals by digital difference filters with integer difference coefficients of nonrecursive filtering [11].

The term "unerroric" (from Latin "errare") means the combined application of methods and procedures to reduce the error of information processing methods and algorithms [12]. As applied to digitalization of multilevel quality control of operator's work, the term "unerroric" means reduction of this control error by hardware-software means of onboard DSP systems [13, 14].

3. RESULTS

As a result of the conducted research, the concept and methodology of hardware-software support for multilevel quality control of OLM operator's work, which takes into account modern and promising achievements in the field of information technology, were proposed and developed. This development is based solely on the use of software for digital processing and screen display of raw data on the results of training OLM operator directly onboard [15, 16]. This concept provides hardware-software modeling onboard of various and including unlikely, but extremal conditions of OLM operator's work and multilevel results using multiparameter simulation models of hydroacoustic environment in training mode of these means operation [17]. Besides, this development provides rejection of additional equipment for screen display and storage of data on training results [18, 19].

This concept assumes creation of software tools for full-fledged current control of professional skills of OLM operator directly at his workplace. It allows for full-fledged automatic quality control of OLM operator's work onboard.

The infological model of multilevel automatic evaluation of OLM operator's training results in the training mode of operation of these facilities is presented in the Figure 1.

However, this model allows describing only formalized process, in which characteristic regularities of the real process are presented and the factors, which are not significant in terms of feasibility of the proposed structure of automatic evaluation of the results of the multilevel quality control of OLM operator's work, are omitted. Increasing the number of controllable parameters of OLM operator training contributes to decreasing the error of controlling his professional competence, but increases the volume of processed information.

Multilevel estimation of training results is made as follows: at the beginning the recorded results of training are entered: $\{Result_n(k_n)\}$, $k_n=1,2,3\ldots K_n$, $n=1,2,3\ldots N$. Then we calculate the quality control parameters of OLM operator and quality control indicators of its work. On their basis the intermediate estimates of the solution of the short-range and long-range locating subtasks directly onboard are made. Then intermediate assessments $\{Test_p(q_p)\}$, $p=1,2,3\ldots P$, $q_p=1,2,3\ldots Q_p$, and final evaluation of training results $Total\_test_0(1)$ are made.

Objectivity of multilevel control of quality of work of OLM operator is carrying out by increasing the number of levels of its pyramidal structure of automatic evaluation of such training results. This structure allows complicating simulation models of undesirable, but possible hydroacoustic conditions in different regions of the World Ocean, fraught with accidents of the carrier OLM.

Digital algorithms of simulation modeling of signal-noise situation in different regions of the World Ocean are based on recurrence transformations of N time samples of digital signal $\{x_n\}$ its digital filtering M-th order by difference filters K_J-th order and J-th order differences with integer difference coefficients $\{\Delta h_{J,k}\}$ and equivalent digital filtering coefficients $\{n_m\}$ following the formula (1) – (2) if $\Delta h_{0,m}=h_m$, $j=1, 2, 3\ldots J$, $k=1, 2, 3\ldots K_J$, $l=n-k$, $m=1,2,3\ldots M$, $M=K_J-J$, $n=0,1,2\ldots N-1$ [20, 21]:

$$\sum_{m=1}^{M} h_m x_{n-m} = \sum_{k_J=1}^{K_J-J} \sum_{k_{J-1}=1}^{k_J} \ldots \sum_{k_j=1}^{k_{j+1}} \ldots \sum_{k_1=1}^{k_2} \sum_{k=1}^{k_1} \Delta h_{J,k} \cdot x_l, \quad (1)$$

$$\Delta h_{J,k}\cdot x_l=\begin{cases}+x_l+x_l+x_l+x_l+x_l,\ if\ \Delta h_{J,k}=+5;\\+x_l+x_l+x_l+x_l,\ if\ \Delta h_{J,k}=+4;\\+x_l+x_l+x_l,\ if\ \Delta h_{J,k}=+3;\\+x_l+x_l,\ if\ \Delta h_{J,k}=+2;\\+x_l,\ if\ \Delta h_{J,k}=+1;\\0,\ if\ \Delta h_{J,k}=0;\\-x_l,\ if\ \Delta h_{J,k}=-1;\\-x_l-x_l,\ if\ \Delta h_{J,k}=-2;\\-x_l-x_l-x_l,\ if\ \Delta h_{J,k}=-3;\\-x_l-x_l-x_l-x_l,\ if\ \Delta h_{J,k}=-4;\\-x_l-x_l-x_l-x_l-x_l,\ if\ \Delta h_{J,k}=-5.\end{cases}\quad(1)$$

The algorithm for generating the values of the results' automatic evaluation of onboard locator operator training directly onboard is shown in the Figure 2 as a logical scheme of input and processing of the input data of this evaluation, followed by the formation and output of its output data. This scheme consists of 43 blocks:

Block 1. Inputting of I value of the pyramidal structure base of the results of onboard radar operator training automatic evaluation directly onboard, the number of J levels of the pyramidal structure of this evaluation, number of N objects of noise direction finding and hydrolocation simulated in the training process, number of K_n of the operator training recorded of OLM in $Result_n(k_n)$, k_n=1,2,3…K_n, n=1,2,3…N, for n-th of simulated object, n=1,2,3…N.

Block 2: Setting the initial (zero) value of the sequence number n of simulated object, n=1,2,3…N.

Block 3. Increasing by 1 the value of ordinal number n of simulated object, n=1,2,3…N.

Block 4. Setting the initial (zero) value of the sequence number k_n of the operator training recorded of OLM $Result_n(k_n)$, k_n=1,2,3…K_n, n=1,2,3…N, for n-th of simulated object, n=1,2,3…N.

Block 5. Increasing by 1 the value of ordinal number k_n of the operator training recorded of OLM $Result_n(k_n)$, k_n=1,2,3…K_n, n=1,2,3…N, for n-th of simulated object, n=1,2,3…N.

Block 6 Inputting of k_n-th value of the operator training recorded of OLM $Result_n(k_n)$, k_n=1,2,3…K_n, n=1,2,3…N, for n-th of simulated object, n=1,2,3…N.

Block 7. Checking if the value of the sequence number k_n of the operator training recorded of OLM $Result_n(k_n)$, k_n=1,2,3…K_n, n=1,2,3…N, for n-th of simulated object, n=1,2,3…N, corresponds to a given value K_n (cycle limit by the number of recorded training results for one object).

Block 8. Checking if the value of the sequence number n of the simulated object, n=1,2,3…N, corresponds to a given value N (cycle boundary by the number of simulated objects).

Block 9. Setting the initial (zero) value of the sequence number k_J of the quality control parameter of the operator's work of OLM $Control\_result(k_J)$, k_J=1,2,3…K_J, $K_J=I^J$.

Block 10. Increasing by 1 the value of ordinal number k_J of the quality control parameter of the operator's work of OLM $Control\_result(k_J)$, k_J=1,2,3…K_J, $K_J=I^J$.

Block 11. Calculation of the value k_J-th of the quality control parameter of the operator's work of OLM $Control\_result(k_J)$, k_J=1,2,3…K_J, $K_J=I^J$.

Block 12. Checking if the value of the sequence number k_J of the quality control parameter of the operator's work of OLM $Control\_result(k_J)$, k_J=1,2,3…K_J, corresponds to the value I^J (cycle boundary by the number of control parameters).

Block 13. Setting the initial (zero) value of the sequence number k_J of the quality control indicator of the operator of OLM $Checking\_factor(k_J)$, k_J=1,2,3…K_J, $K_J=I^J$.

Block 14. Increasing by 1 the value of ordinal number k_J of the control indicator of the work quality of the operator of OLM $\{Checking\_factor(k_J)\}$, k_J=1,2,3…K_J, $K_J=I^J$.

Block 15. Calculation of the value k_J-th of the quality control indicator of the operator of OLM $Checking\_factor(k_J)$, k_J=1,2,3…K_J, $K_J=I^J$.

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Block 16. Entering the values of k_j-th normative indicator of the work quality of the operator of OLM *Normative*(k_J), k_J=1,2,3…K_J, $K_J=I^J$, and k_J-th normative criterion of the work quality of the operator of OLM *Criteria_norma*$_i$(k_J), i=1,2,3…I-1, k_J=1,2,3…K_J, $K_J=I^J$.

Block 17. Calculation of the value k_J-th intermediate assessment of the operator's solution of OLM subtasks to determine the presence of simulated object and its parameters when it solves the problems of noise direction finding and hydrolocation *Subtest*(k_J), k_J=1,2,3…K_J, $K_J=I^J$.

Block 18. Checking if the value of the sequence number k_J intermediate assessment of the operator's solution of OLM subtasks to determine the presence of simulated object and its parameters when it solves the problems of noise direction finding and hydrolocation *Subtest*(k_J), k_J=1,2,3…K_J, corresponds to the value I^J (cycle boundary by the number of intermediate assessments).

Block 19. Setting the initial (zero) value of the sequence number k_j of the intermediate evaluation of the operator's solution of OLM equipment subtasks to determine the presence of simulated object and its parameters when it solves the problems of noise direction finding and hydrolocation *Subtest*(k_J), k_J=1,2,3…K_J, $K_J=I^J$.

Block 20. Setting the initial (zero) value of the sequence number $k_{J\text{-}1}$ intermediate evaluation of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation *Test*$_{J\text{-}1}$($k_{J\text{-}1}$), $k_{J\text{-}1}$=1,2,3…$K_{J\text{-}1}$, $K_{J\text{-}1}=I^{J\text{-}1}$, on ($J$-1)-th level of the pyramidal structure of the automatic evaluation of the results of its training.

Block 21. Increasing by 1 the value of ordinal number $k_{J\text{-}1}$ intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation *Test*$_{J\text{-}1}$($k_{J\text{-}1}$), $k_{J\text{-}1}$=1,2,3…$K_{J\text{-}1}$, $K_{J\text{-}1}=I^{J\text{-}1}$, on ($J$-1)-th level of pyramidal structure of automatic evaluation of the results of OLM training directly onboard.

Block 22. Setting the initial value *Subtest*(k_J), k_J=1,2,3…K_J, $k_{J\text{-}1}$-th intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation *Test*$_{J\text{-}1}$($k_{J\text{-}1}$), $k_{J\text{-}1}$=1,2,3…$K_{J\text{-}1}$, $K_{J\text{-}1}=I^{J\text{-}1}$, on ($J$-1)-th the level of pyramidal structure of automatic evaluation of the results of onboard locator operator training directly onboard.

Block 23. Increasing by 1 the value of ordinal number k_J intermediate assessment of the operator's solution of OLM subtasks to determine the presence of simulated object and its parameters when it solves the problems of noise direction finding and hydrolocation *Subtest*(k_J), k_J=1,2,3…K_J, $K_J=I^J$.

Block 24. Checking for a null value k_J-th intermediate assessment of the operator's solution of OLM subtasks to determine the presence of simulated object and its parameters when it solves the problems of noise direction finding and hydrolocation *Subtest*(k_J), k_J=1,2,3…K_J.

Block 25. Checking the value correlation $k_{J\text{-}1}$-th intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation *Test*$_{J\text{-}1}$($k_{J\text{-}1}$), $k_{J\text{-}1}$=1,2,3…$K_{J\text{-}1}$, $K_{J\text{-}1}=I^{J\text{-}1}$, and the value k_J-th intermediate assessment of the operator's solution of OLM subtasks to determine the presence of simulated object and its parameters when it solves the problems of noise direction finding and hydrolocation *Subtest*(k_J), k_J=1,2,3…K_J.

Block 26. Setting a value *Subtest*(k_J), k_J=1,2,3…K_J, $k_{J\text{-}1}$-th intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation *Test*$_{J\text{-}1}$($k_{J\text{-}1}$), $k_{J\text{-}1}$=1,2,3…$K_{J\text{-}1}$, $K_{J\text{-}1}=I^{J\text{-}1}$, on ($J$-1)-th the level of pyramidal structure of automatic evaluation of the results of onboard locator operator training.

Block 27. Outputting the value $k_{J\text{-}1}$-th intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation *Test*$_{J\text{-}1}$($k_{J\text{-}1}$), $k_{J\text{-}1}$=1,2,3…$K_{J\text{-}1}$, $K_{J\text{-}1}=I^{J\text{-}1}$, on ($J$-1)-th the level of pyramidal structure of automatic evaluation of the results of onboard locator operator training.

Block 28. Checking if the value of the sequence number k_J intermediate assessment of the operator's solution of OLM subtasks to determine the presence of simulated object and its parameters when it solves the problems of noise direction finding and sonar *Subtest*(k_J), k_J=1,2,3…K_J, corresponds to the value I^J (cycle boundary by the number of intermediate assessments).

Block 29. Setting the initial (zero) value of the sequence number j level of pyramidal structure of automatic evaluation of the results of onboard locator operator training directly onboard.

Block 30. Setting the initial (zero) value of the sequence number k_{j+1} intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation $Test_{j+1}(k_{j+1})$, $k_{j+1}=1,2,3\ldots K_{j+1}$, $K_{j+1}=I^{j+1}$, on (j+1)-th level of the pyramidal structure of the automatic evaluation of the results of its training.

Block 31. Setting the initial (zero) value of the sequence number k_j intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation $Test_j(k_j)$, $k_j=1,2,3\ldots K_j$, $K_j=I^j$, on j-th level of the pyramidal structure of the automatic evaluation of the results of its training.

Block 32. Increasing by 1 the value of ordinal number k_j intermediate evaluation of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation $Test_j(k_j)$, $k_j=1,2,3\ldots K_j$, $K_j=I^j$, on j-th level of the pyramidal structure of the automatic evaluation of the results of its training.

Block 33. Setting a value $Test_{j+1}(k_{j+1})$, $k_{j+1}=1,2,3\ldots K_{j+1}$, $K_{j+1}=I^{j+1}$, k_j intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation $Test_j(k_j)$, $k_j=1,2,3\ldots K_j$, $K_j=I^j$, on j-th level of the pyramidal structure of the automatic evaluation of the results of its training.

Block 34. Increasing by 1 the value of ordinal number k_{j+1} intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation $Test_{j+1}(k_{j+1})$, $k_{j+1}=1,2,3\ldots K_{j+1}$, $K_{j+1}=I^{j+1}$, on (j+1)-th level of the pyramidal structure of the automatic evaluation of the results of its training.

Block 35. Checking for a null value k_{j+1} intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation $Test_{j+1}(k_{j+1})$, $k_{j+1}=1,2,3\ldots K_{j+1}$, $K_{j+1}=I^{j+1}$, on (j+1)-th level of the pyramidal structure of the automatic evaluation of the results of its training.

Block 36. Checking the value correlation k_j intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation $Test_j(k_j)$, $k_j=1,2,3\ldots K_j$, $K_j=I^j$, and the value k_{j+1} intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation $Test_{j+1}(k_{j+1})$, $k_{j+1}=1,2,3\ldots K_{j+1}$, $K_{j+1}=I^{j+1}$.

Block 37. Setting a value $Test_{j+1}(k_{j+1})$, $k_{j+1}=1,2,3\ldots K_{j+1}$, k_j-th recommended intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation $Test_j(k_j)$, $k_j=1,2,3\ldots K_j$, $K_j=I^j$, on j-th level of the pyramidal structure of the automatic evaluation of the results of its training.

Block 38. Outputting the value k_j-ой intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation $Test_j(k_j)$, $k_j=1,2,3\ldots K_j$, $K_j=I^j$, on j-th level of the pyramidal structure of the automatic evaluation of the results of its training.

Block 39. Checking the value correlation of the sequence number k_{j+1} recommended intermediate assessment of the operator's solution of onboard radar tasks of noise direction finding and hydrolocation $Test_{j+1}(k_{j+1})$, $k_{j+1}=1,2,3\ldots K_{j+1}$, and the value I^{J-j+1} (cycle boundary by the number of intermediate assessments).

Block 40. Increasing by 1 the value of ordinal number j level of the pyramidal structure of the automatic evaluation of the results of its training.

Block 41. Checking the value correlation of the sequence number j level of pyramidal structure of automatic evaluation of the results of onboard locator operator training directly onboard and the value J (cycle boundary by the number of levels of the pyramidal structure).

Block 42. Setting a value $Test_0(k_0)$, $k_0=I^0$, of final evaluation of the results of the training of the operator of OLM $Total\_test_l(K_0)$, $K_0=I^0$.

Block 43. Outputting the value of final evaluation of the results of the training of the operator of OLM $Total\_test_l(K_0)$, $K_0=I^0$.

4. DISCUSSION

Simulator training programs for airborne radar operators have undergone significant changes since Manila Amendments to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, which involves more than 70 countries [22-24]. This Convention establishes international standards for the training of operators of airborne radar aids and provides provisions to ensure that they are properly trained and develop their professional skills in accordance with the requirements of International Maritime Organization. The current system as a whole complies with the safety requirements of navigation, however, as new ships appear and international requirements for the competence of on-board radar equipment operators are updated, new requirements are being formed for their training and simulator training and the emphasis on their demand on ships is shifting.

At the same time, according to the American press, the preparation and training of the operator of airborne radar means are associated with very significant costs. For this and a number of other reasons, such as the difficulty of evaluating the results of its professional training and its dependence on hydrometeorological conditions, new organizational forms and cheaper methods and technical means of its preparation are needed. The well-known results of research conducted by the International Maritime Organization confirm that the most rational way to train operators of onboard radar facilities is their education and training with the help of electronic simulators, which have ample opportunities to simulate a real hydroacoustic situation in different regions of the World Ocean.

The main advantage of such simulators, according to the Americans, is a significant financial savings in the course of training and training. Therefore, relatively high costs for the development, production and installation of training equipment quickly pay off. In addition, with simulator training, skills are developed faster and independence is acquired when making decisions in difficult conditions of intensive navigation.

Thus, simulators, which can and should be installed on ships, make it possible to improve previously acquired skills through systematic training of on-board radar equipment operators directly on board.

Unfortunately, in the literature there are different points of view on the topic of the study, therefore, in this article, it is proposed to provide an error in the quality control of the work of the operator of on-board facilities due to the hardware and software for his training directly on board. The data presented in the article differ from previously published data in that an error of automatic quality control of OLM operator directly on board is provided without the use of additional equipment through the use of digital methods of deductive information processing. The proposed and developed methodology of hardware and software for multilevel quality control of OLM operator's work takes into account the experience of Russian and foreign research developments. This methodology is a combination of the following DSP methods [25]:

- digital method for calculating the benchmark indicators of OLM operator quality;
- digital method of comparative analysis of control and normative quality indicators of OLM operator's work;
- digital method for calculating intermediate evaluations of OLM operator's solution of short-range and long-range locating subtasks;
- digital method for calculating the final assessment of the results of OLM operator's training.

The proposed and developed methodology allows minimizing and optimizing the composition of control and normative indicators of quality of the operator's radar stations and intermediate assessments of its solution of tasks and subtasks of near and far location in the training mode of operation of such means.

The numerical value of each digital readout of hydroacoustic signal x_n can be represented as a sum of the numerical value of the previous time readout x_{n-1} and the numerical value of the order 1 increment $\Delta x_{1,n}$ following the formula (3) if n>1 [26]:

$$x_n = x_{n-1} + \Delta x_{1,n} \ , \qquad (3)$$

The numerical values of this increment can be represented as the sum of the numerical value of the previous increment of order 1 $\Delta x_{1,n-1}$ and the numerical value of the order 2 increment $\Delta x_{2,n-1}$ following the formula (4) if n>1 etc. up to the order I increments if i=1,2,3…I [27]:

$$x_n = \sum_{n_I=0}^{n-1} \sum_{n_{I-1}=0}^{n_i-1} \dots \sum_{n_i=0}^{n_{I+1}-1} \dots \sum_{n_1=0}^{n_2-1} \sum_{n=0}^{n_1-1} \Delta x_{I,n} \ , \qquad (4)$$

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The reliability of the research results is confirmed by their compliance with the known results of scientific developments.

5. CONCLUSIONS

As a result of solving the tasks set, the principles and methods of multi-level assessment with varying degrees of detail at different levels for short-term training of on-board radar facility operators were proposed and developed, taking into account the specifics of hydrometeorological conditions before the next flights.

The novelty of the proposed solution to the tasks set lies in the use of digital methods of deductive information processing to ensure automatic control of the operation of OLM operator directly on board only by hardware without the use of additional equipment. Therefore, the usefulness of the results of the study is in the proposed possibility of reducing the hardware costs for the hardware-software implementation of such control.

The conducted research has shown and confirmed the possibility of reducing the error of quality control of OLM operator by the results of its training in the training mode of operation of these tools onboard the ship.

Hardware-software means of unerroric automatic estimation of its results provide multilevel control of work quality of this operator directly on its workplace.

Application of digital methods and electronic devices of deductive signal processing allows reducing hardware costs for hardware-software implementation of algorithms of such evaluation on PLIC.

REFRENCES

[1].A.I. Maron, T.K. Kravchenko, and T.Y. Shevgunov, "Estimation of resources required for restoring a system of computer complexes with elements of different significance", *Business Informatics*, Vol. 13, No. 2, 2019, p. 18.

[2].R.R. Anamova, L.V. Bykov, and D.A. Kozorez, "Algorithm for designing professional retraining programs based on a competency approach", *Education Sciences*, Vol. 10, No. 8, 2020, p. 191.

[3].A.I. Kanashchenkov, A.M. Matveev, and S.V. Novikov, "Measuring System for Use in RadarSystem Development", *Russian Engineering Research*, Vol. 38, No. 11, 2018, p. 896.

[4].A.Y. Burova, "Concept of multistage discrete Fourier transform without performing multiplications", *Journal of Physics: Conference Series*, Vol. 1889, No. 2, 2021, 022003.

[5].A.Yu. Burova, "Digital signal processing without performing arithmetic multiplication operations", *Amazonia Investiga*, Vol. 9, No. 25, 2020, p. 200.

[6].A.Yu. Burova, and T.O. Usatenko, "Digital Algorithms for the Discrete Frequency Selection of Signals that Do Not Use Algorithmic Multiplication Operations", *TEM Journal*, Vol. 9, No. 2, 2020, p. 501.

[7].A.Yu. Burova, "Quality control of the operator of onboard location facilities", *Standards and Quality*, No. 4, 2020, p. 96.

[8].A.Y. Burova, A.V. Ryapukhin, and A.R. Muntyan, "Reduced hardware costs with software and hardware implementation of digital methods multistage discrete Fourier transform on programmable logic devices", *Amazonia Investiga*, Vol. 9, No. 27, 2020, p. 227.

[9].V.V. Vityazev, and S.V. Vityazev, *"Digital signal processing processors TMS320C67x of Texas Instruments"*, Ryazan State Radio Engineering University, Ryazan, 2007.

[10]. V.S. Speransky, *"Signal microprocessors and their application in telecommunication systems and electronics"*, Hot Line – Telecom, Moscow, 2008.

[11]. A. Burova, "Digital Signal Multi-Stage Discrete Fourier Transform and Its Practical Applications", *2021 23rd International Conference on Digital Signal Processing and its Applications (DSPA),* 2021, p. 1-5.

[12]. A.Y. Burova, and V.V. Kabakov, "Unerroric" of multistage discrete Fourier transform of digital signal without arithmetic operations of multiplication", *Amazonia Investiga*, Vol. 9, No. 25, 2020, p. 429.

[13]. D.I. Kaplun, and T.V. Merkucheva, "*New method of filters synthesis on PLD. Radioelectronics issues*", OJSC "Central Research Institute "Electronics", Moscow, 2009.

[14]. A.A. Lanne, and T.V. Merkucheva, "Filters with double symmetry", *Higher*

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Education News. Radio electronics, Vol. 52, No. 5, 2009, p. 46.

[15]. S.N. Eliseev, "Synthesis of prefilters for constructing NDF with a reduced number of multipliers", *Higher Education News. Radio electronics*, Vol. 32, No. 12, 1989, p. 22.

[16]. L.A. Zalmanzon, *"Fourier, Walsh, Haar transforms and their application in control, communication, and other fields"*, Nauka, Moscow, 1989.

[17]. V.E. Chebotarev, V.V. Brezitskaya, I.V. Kovalev, I.N. Kartsan, Y.N. Malanina, and A.O. Shemyakov, "Solving navigation-temporal tasks in different coordinate systems", *IOP Conference Series: Materials Science and Engineering*, Vol. 450, No. 2, 2018, 022029.

[18]. L.M. Goldenberg, B.D. Matyushkin, and M.N. Polyak, *"Digital Signal Processing: a Guide"*, Radio and communications, Moscow, 1985.

[19]. V.P. Eremeev, A.G. Matveev, and A.V. Anufrieva, "NDF implemented without multiplication", *Computer Modeling & New Technologies*, No. 3, 1999, p. 83.

[20]. A. Burova, "Reducing the Error of Digital Algorithms for Deductive Signal Processing Based on Their Multi-Stage Discrete Fourier Transform by the Difference Digital Filters", *2020 22th International Conference on Digital Signal Processing and its Applications (DSPA)*, 2020, p. 1.

[21]. V.V. Kabakov, A.E. Sorokin, and A.V. Ryapukhin, "Relations between typological personality traits and mechanisms of psychological defense", *Laplage em Revista*, Vol. 7, No. D, 2021, p. 517.

[22]. C.S. Brookman, "IMO Environmental Regulations—Is There a Case for Change to the Standard Entry-into-Force Requirements?", *Marine technology and SNAME news*, Vol. 39, No. 04, 2002, pp. 232-238.

[23]. C.K. Hadjistassou, *"International maritime organization: rethinking marine environmental policy"*, Massachusetts Institute of Technology, Massachusetts, 2005.

[24]. T. Hofer, "Tanker safety and coastal environment: prestige, erika, and what else?", *ESPR-Environmental Science and Pollution Research-International*, Vol. 10, No. 1, 2003, pp. 1-5.

[25]. V.S. Speransky, and T.P. Kosichkina, *"Signal microprocessors and their application in communication systems and electronics"*, Hot Line – Telecom, Moscow, 2021.

[26]. V.B. Steshenko, *"PLD implementation by firm ALTERA: element base, design system and hardware description languages"*, DMK-Press, Moscow, 2016.

[27]. P.A. Ukhov, B.A. Dmitrochenko, and A.V. Ryapukhin, "The practice of technological deception in videoconferencing systems for distance learning and ways to counter it", *Amazonia Investiga*, Vol. 10, No. 40, 2021, p. 153.

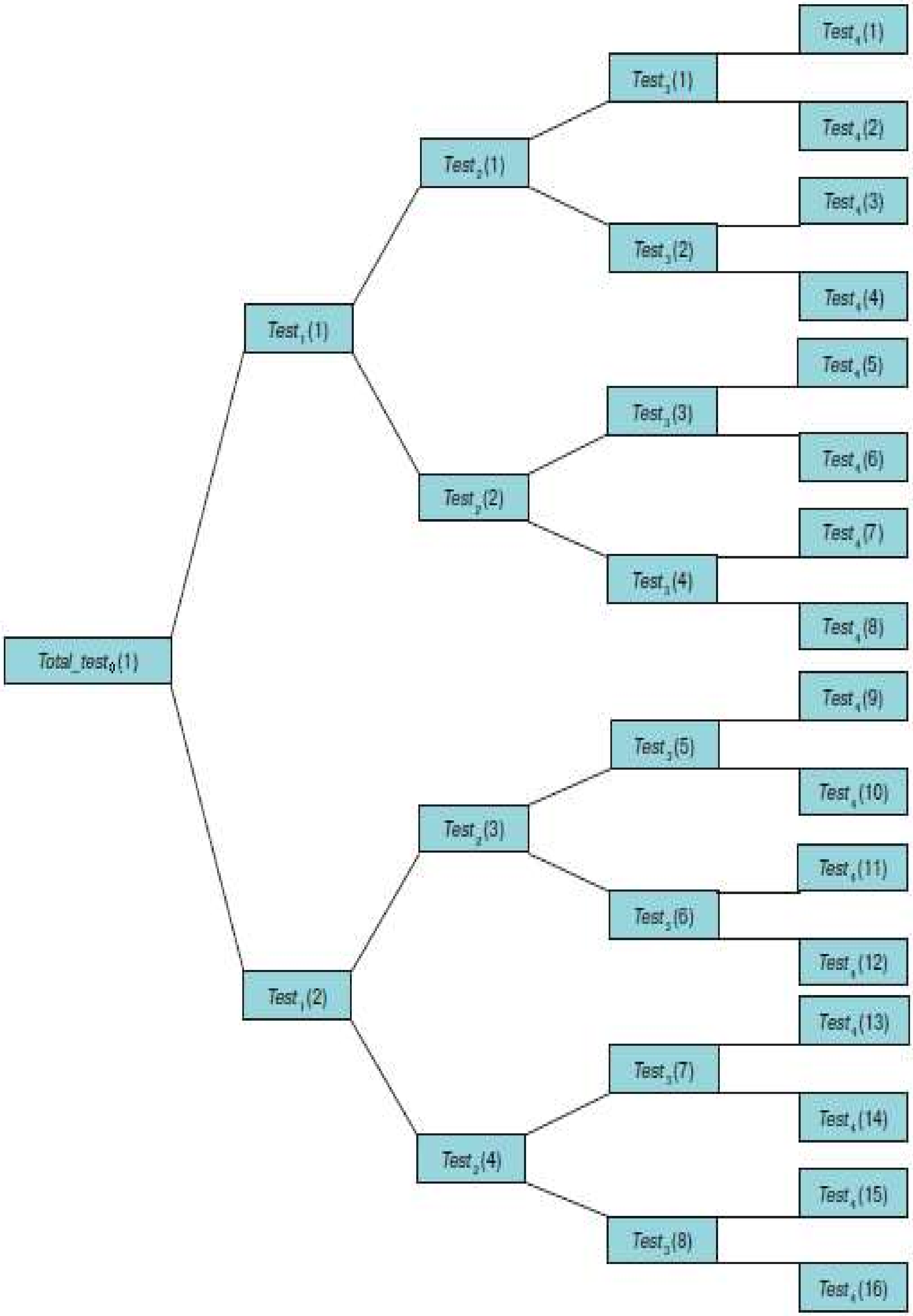

Figure 1: Infological model of multilevel automatic evaluation of OLM operator training results in the training mode of operation of these facilities

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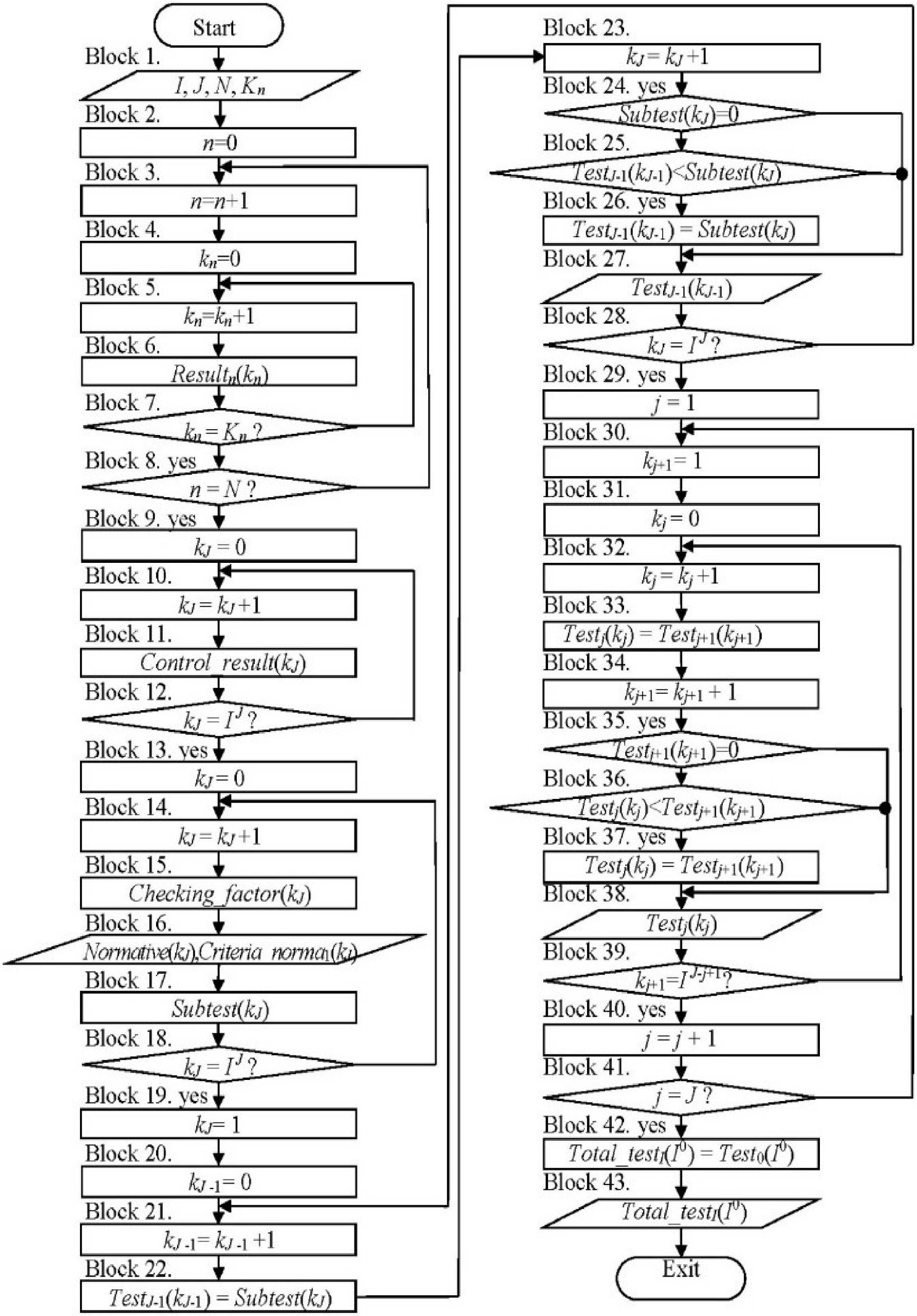

Figure 2: Algorithm for generating values of automatic evaluation of the results of onboard locator operator training directly onboard