Choice of Ship Management Strategy Based on Wind Wave Forecasting

Lyudmila Kravtsova[0000-0002-0152-635X], Tatyana Zaytseva[0000-0001-6780-719X] and Anna Puliaieva[0000-0003-0595-6709]

Kherson State Maritime Academy, 20 Ushakova Str., Kherson, 73000, Ukraine
limonova@ukr.net, sunny@ksu.ks.ua, leon85517@gmail.com

Abstract. The foundation of scientific research is being laid during the learning of navigator in higher school. As in any technical institution, in Kherson State Maritime Academy such basic disciplines as Higher Mathematics, Physics, and Information Technologies are taught from the first year of study. Curricula based on a competent approach to marine specialist training provides not only mastering the one or the other discipline, but also able to use the obtained knowledge in the professional activity. This article focuses on such an important question as a choice of ship management strategy based on the natural phenomena forecasting conducted on the results of statistical observations on environment behaviour, which surrounds a ship. Since task solution of analysis and forecasting is related with the usage of mathematical apparatus, study this theme within of the discipline "Information Technologies", using possibilities of electronic tables, is supported by mathematical methods of construction of regression equations, solution of algebraic equations systems and in more difficult cases – solution of differential equations systems in partial derivatives. The modern development of information technologies and the power of software allow filling the educational material of disciplines with applied, professionally-oriented tasks. The using of mathematical modelling apparatus allows students to be able to solve such tasks.

Keywords: Forecasting, Natural phenomena, Wind wave, Mathematical model, Regression equation.

1 The general problem statement and its actuality

Systematic study of researching results of water resources behaviour, weather conditions, natural phenomena recorded in the form of statistic data contributed to the development of the methodological basis of analysis and forecasting processes which affect to the strategy of ships various purpose using in the all human activities. The analysis of researching results often makes possible to conclude about cyclicity of phenomena. It allows forecasting the climatic peculiarities of the region at one or another time interval. It ensures the safest ship's movement tactics.

The information about dangerous and especially dangerous phenomena that can harm or break the terms of the voyage has a special value for the ship and its crew. The largest number of studies is taking place in busy navigation and fishery. The distribution maps of water temperature and wave height on the seas and oceans are built by received information, and meteorological characteristics, compiled on these data.

Forecasting of natural phenomena that have different, both positive and negative influence on the strategy of ships using is the integral part of the scientific approach to management decision. Decision making by the chosen criterion is particularly relevant in the extreme working conditions at the sea. Sometimes ship's fate, health and lives of the crew depend on that decision. The foundation of forecasting is the base of the main features of studied phenomenon formed accordingly the analytical support of the future mathematical model.

The current stage of development of marine forecasts is characterized by using traditional and new methods of forecasting. Besides, modern computer technologies are widely used in the development of forecasting methods and in making operational marine forecasts.

In Kherson State Marine Academy (KSMA) the first year students study the discipline "Information Technologies". Its curriculum has several chapters "Work in Spreadsheets", "Conducting of calculations for navigators", "Solving of optimization tasks using MS Excel", "Data analysis and forecasting". The purpose of studying of the course material is not mastering the amount of knowledge in subject field activity but to form skills, abilities and competences which will provide the ability to analyze information and predict the behavior of the system for the next period, and to find the necessary ways to solve problems related to the performance of social and professional functions. The applied orientation of the discipline allows qualitatively forming subject competences connected with the using of data processing methods, calculation methods, mathematic and information modelling, business graphics.

This article focuses on the one of discipline chapter "Data analysis and forecasting" on the example of mathematical modelling of the phenomena forecasting connected with professional marine activity based on results of statistical observations of the water environment behaviour.

2 Analysis of recent research and publications, which launched the solution to this problem

Vasilii V. Shuleikin [25] has been greatly contributed to the tropical storms, ice, and wind wave researches. His works are in fact the theoretical basis of methods for predicting water temperature and have received the further development in modern researches of the features and regularities of the water environment. The study [2] is concentrated on analysis and methods of solving operational oceanographic service tasks. It covers such areas as hydrologic prediction (heat and water balance, ocean-atmosphere interaction), windswell forecasts, sea current and level forecasts, and ice prediction. The automated calculation system of optimal navigation course is built based on short- and long-term forecasts.

The works of Igor V. Lavrenov [14], Evgenii S. Nesterov [19], Leonid I. Piterbarg [21] are dedicated to mathematical modelling of wind swell in the spatially and nonhomogeneous ocean. Aleksandr P. Khain [10] paid much attention to mathematical modelling of tropical cyclones. The manual "Marine Forecasting" [3] focuses directly on the methodological, statistical, mathematical fundamentals of the forecasting and reliability assessment, where detailed information on the gathering methods and analysis of data on the state of the sea and the oceans is offered, physicomathematical models of the short-term, long-term and over long-term forecasts of the main elements of the marine regime are considered. For example, the wind swell forecast provides practical advice on how to navigate the ocean.

Foreign researchers have also made a great contribution to analysis and forecasting of processes that affect to safe navigation (K. D. Pfeiffer [20], John Andrew Ewing [7] and others).

Fundamentals of numerical methods for solving problems are published in scientific and educational publications by Liudmyla I. Bilousova [4], Steven C. Chapra [5], Joe D. Hoffman [9], Illia O. Teplytskyi [23], Serhiy O. Semerikov [24]. Modern applications of numerical methods are associated with the use of information technology, so many scientists consider the MS Excel spreadsheet as a computer environment for modeling, such as Mohamed A. El-Gebeily [6] and Leonid O. Flehantov [8].

Problems of introduction of computer modelling in the study of informatics disciplines paid attention to Hennadiy M. Kravtsov [11], Lyudmila M. Kravtsova [27], Maiia V. Marienko [16], Oksana M. Markova [15], Yevhenii O. Modlo [18], Pavlo P. Nechypurenko [17], Yaroslava B. Samchynska [22], Mariya P. Shyshkina [26], Tatyana V. Zaytseva [27].

Modern operative oceanography develops by integration of many countries' efforts. International projects involving Germany, Italy, Portugal and the Netherlands are being successfully implemented. Understanding of importance direction in the study of World Ocean allows developing research effort that an improvement ship coordination and disaster prevention systems to ensure safe navigation are resulting.

3 Solving basic problems

Hydro-meteorological stations are the main source of statistical data. Their information is data about the past, present and future state of the seas and oceans, based on observations and appropriate methods of analysis and forecasting of oceanographic characteristics. Increasing of incoming information from all of its sources requires the introduction of new methods for the collection, transmission, processing and storage of hydro meteorological information. The use of modern computer technologies makes it possible to automate the process. It is clear, research work which is being done in this direction and its application are needed.

Unnatural hydro-meteorological conditions are particularly dangerous and scientific interested. Hydro-meteorological processes that, in terms of time, intensity, duration and area of occurrence, can cause significant damage or natural disasters relate to hydrologic extremes. There are dangerous and especially dangerous hydrological phenomena [13] on the seas and oceans, such as:

1. Irregular sea level variations (above or below critical points) in which populated places and coastal installations are flooded, ships and other household objects are damaged, and navigation is stopped.
2. Tsunamis that cause a sea level rise of 2 m or more.
3. Wave height is 8 m or more in the oceans; and wave height in the sea that are dangerous for navigation, fishing and coastal installations.
4. Tropical storms and typhoons when wind speed is 35 m/s and more.
5. The appearance of the ice cover at an unusually early date; is repeated no more than once every 10 years.
6. The pressure drift of floating ice that threatens oil rigs, flyovers and other facilities.
7. Ship icing when rate of ice growth is 0.7 cm/h or more.
8. Strong riptide in the port waters.

Danger warning of port services, port-side territories, ships in the waters, maritime industries and population are faced by and caused by adverse hydrologic events is an important practical task. The initial materials for the warning are:

1. Forecast of an expected hydrologic hazard and the time of its occurrence.
2. Hydrologic hazard criteria.

Forecasting Methodological Bases. Hydro-meteorological condition forecasting provides for a scientific evidence system, development of different hypotheses and using methods that characterized by mathematical formalization [9]. The variability of oceanological processes depends on a rangier of factors, so marine forecasts tend to have a probabilistic nature. The long-term prediction of any characteristics of the seas and oceans regime can only be made approximately because all influencing factors to this process are unknown. Next, the forecasting methods as usually are based on the using discrete values of characteristics which also brings a certain error in the study results of this process.

Applying of cyclicity that discovered on a long series observations of forecasted characteristic is useful in a long-range marine prediction techniques besides physical patterns. Some methods of over long term forecasts take into account the influence of space and global geophysical factors (solar activity, long tides, fluctuations in the Earth's rotation axis, etc.).

Usage of the linearized system of hydrodynamic equations and simultaneously a non-linear model development is the methodological basis for the work on numerous long-term forecasts. Applying of statistical characteristics to solve the hydrothermodynamics equations is quite possibly. Space-time correlation relations between phenomena are established with the help of statistical methods. The advantage of using this approach to the forecasting problem is that own correlation matrix functions a priori contain useful information about the structure of some or other hydro-meteorological fields.

Methods of probability theory, mathematical statistics, factor and spectral analysis, differential equations describing physical processes whose characteristics form the basis of research are most commonly used as the mathematical apparatus in marine hydrologic prediction.

So, two main directions are considered in the development of marine forecasting techniques: physicostatistical and hydrodynamic. Using of the physical hypothesis that reveals the interrelations between predictors (factor feature or prediction parameters) and predictant (the resultant factor, or value that at the some point in time is determined using predictors) underlies physicostatistical direction. The physical hypothesis facilitates the task of applying statistical methods in forecasting.

Statistical methods for forecasting are provided an opportunity to evaluate the development of hydro-meteorological processes in the future based on the results of past observations using knowledge of probability characteristics of these processes. An observation series of the predicted characteristic and factors that it depends on is composed to establish a link between investigated quantities. Methodology development suitable for making operational forecasts is a complex scientific study that can be broken into several stages.

At the first stage of study a general patterns between phenomena are identified and main factors are determined. As forecasting experience has shown, many predictors that are used in the methods do not improve forecast quality. The optimal number of predictors is three or four as a rule. The optimal number of predictors is three or four as a rule. The optimal number of predictors understands a set of predictors when further increase their number does not lead to an increase of the correlation coefficient and improving forecasting results. The right decision when choosing the number of predictors is greatly facilitated development of forecast method and ensures the increased reliability of operational forecasts.

In the second phase of forecast methodology development, a general physical regularity that was previously identified applies to specific physical and geographical sea conditions. For this purpose, observational data that needed to develop of the method are carefully analysed for representativeness and comparability of observations in different years. Methods of operative forecast are usually local because World Ocean basins are very different on physico-geographical and ocean conditions. Attempts of researchers to create a common forecasting methods that would be suitable for large areas of the seas and oceans have not yet led to positive results, because of global differences in the basic characteristics of these objects.

A third stage is start of receiving predictive quantitative dependencies. Graphical comparison of predicted element with predictors should be considerate as a visual way to find connections. This technique gives possible not only to establish the existence of a statistical relationship, but also to determine the type of its dependency. A detailed analysis of the deviations should be made, and determine the reasons that led to a disturbance in the general regularity. The wider points' variation on the link's graph, the more influence degree of random factors.

Development of forecasting method of the oceanological phenomena, such as: wind-wave, marine currents, fluctuations, water temperature, etc., usually begins from with analysing and generalizing ideas about the general physical regularity of predicted phenomena, searching for factors that affect its changes in time and area, and identify among them the most informative in the prognostic sense. Other words, a researcher accepts the general provisions (hypothesis) based on the examination of priory information about these phenomena that characterize relation, which must be found between the predicted phenomenon (predictive) and factors that cause it (predictors).

The next stage is the choice of the most adequate mathematical apparatus, which would allow the best approach to the problem, that is, the creation of a reliable forecast method.

Then, hydrodynamic methods of the forecast are based on solving of hydro- and thermodynamics equations. As of today, with some simplifications, numerical analysis for short-term forecasts of storm surges, water temperatures of the upper quasi-homogeneous ocean layer and its thickness, ice formation period, ice thickness increasing and melting of snow and ice cover have developed. For example, when ocean physical processes are described for Southern Hemisphere, such equations of thermodynamics of turbulent liquid can be accepted:

for moving:

$$\frac{du}{d\tau} = -\frac{1}{p}\frac{\partial p}{\partial x} + fv + \frac{\partial}{\partial z}k'\frac{\partial u}{\partial z} \quad (1)$$

$$\frac{du}{d\tau} = -\frac{1}{p}\frac{\partial p}{\partial y} - fu + \frac{\partial}{\partial z}k'\frac{\partial v}{\partial z} \quad (2)$$

$$\frac{\partial p}{\partial z} = g\rho \quad (3)$$

for continuity:

$$div_h u + \frac{\partial \omega}{\partial z} = 0 \quad (4)$$

for heat distribution:

$$\frac{\partial t_\omega}{\partial \tau} + u \cdot grad_h t_\omega + \omega\frac{\partial t_\omega}{\partial z} = \frac{\partial}{\partial z}k_{t\omega}\frac{\partial t_\omega}{\partial z} + \sum Q \quad (5)$$

for salt distribution:

$$\frac{\partial S}{\partial \tau} + u \cdot grad_h S + \omega\frac{\partial S}{\partial z} = \frac{\partial}{\partial z}k_S\frac{\partial S}{\partial z} \quad (6)$$

for state of sea water:

$$\rho = \rho(t_\omega, S, P_\omega) \quad (7)$$

where all parameters of the relation represent some characteristics of sea water condition.

This example illustrates, how complex the mathematical model of the phenomenon studied can be. The solution of hydrodynamic equations without professional mathematical training is practically impossible.

Students of Kherson State Maritime Academy learn discipline Information Technologies in the first year. It is clear that the first-year student hasn't sufficient mathematical knowledge to comprehend the essence of such equations. However, understanding of the importance of the data analysis and prediction, the main methods for their solving, possibility using in the professional navigational workload – quite an achievable task. Weak students' knowledge in the field of mathematics is a one of the problems that first-year students face from one side and teachers, which work with them from the other side. Therefore, the task before teacher is to systematize them knowledge, increase level of understanding mathematical formulas, recognizing them not as just "picture", but as an instruction for action that result is strategy to ship and crew management. And thanks to the applied aspect of mathematical models, student interest to natural-science disciplines can be increased.

Most simple way to objectively realization of information that's based on statistical observations for forecast of ocean phenomena is constructing a regression equation. Application of the mathematical statistics apparatus provides availability of long enough series of observations for predicant and predictors. These temporary series can be considered as system of random correlated variables. The normalized correlation matrix is a good feature of relations in such systems.

Functional dependence is a most studied kind of link between quantities, in term of implementation, when each value of one quantity (factor sign) X corresponds to quiet defined value (result sign) Y. But in practice, as a rule, have not dealt with functional dependencies, but of statistical ones. In this case, for each value of one quantity corresponds many possible values of another. Dispersing of possible values explains by the influence of many additional factors, which usually neglected when relations between quantities are studied. A dimensionless correlation coefficient characterizes the measure of linear dependence between variables, that in absolute value no more than one: $abs(r) \leq 1$.

Correlation coefficient equals zero for independence quantities X and Y. Equality of the correlation coefficient to zero means that linear dependence is absent (but does not eliminate nonlinear dependence). Another correlation methods are used in nonlinear relationship. The closer the absolute value of correlation coefficient is to one, the closer the linear dependence between quantities. Equality of correlation coefficient to one means that functional dependence is present between X and Y. Correlation coefficients don't change when starting point and measurement scale of quantities of X and Y are changed. It makes possible for significantly simplify the calculation by selecting a convenient starting point (X_0, Y_0) and corresponding units of scale. The correlation coefficient and regression equation for both variables can be found approximately from the correlation chart, and more accurately – by method of least squares.

First-year students, at the time of studying the topic "Data Analysis and Forecasting. Linear and quadratic regressions" have fully mastered the basic techniques of MS Excel spreadsheets, have skills (in accordance with a course syllabus) to solve systems of linear equations using the Cramer method and matrix method, calculating the inverse matrix and matrix multiplication operations using built-in functions. In terms of obtaining parameters of the linear and quadratic dependences in accordance to the method of least squares for building of an optimal analytical function, that's enough, if student's understanding of the problem formulation, its solving methods and analysis of the obtained results. Appropriate theoretical material and stepwise solution of the classical task of the task of finding dependency parameters of linear and quadratic regression for students are posted on the discipline "Information technologies" webpage of the E-learning system KSMA (based on the Moodle).

Our objective is to show student, the future navigator, how important to have the analysis skills of real situation based on observations, to forecast, to apply their knowledge in practice, to make the right management decision. For this purpose, real application tasks are proposed to the student after the techniques of solving the classical task of linear and quadratic dependence equations constructing founded by the table data (results of observation) he has mastered.

Consider a typical task of wave height forecasting depending on wind speed and the duration of its effects (forecasts of wind waves).

As a result of the enhancement of sea economic activity, the knowledge of its condition and forecast changes is of great practical importance [9]. Accordingly, the role of the wind swell forecast significantly increases.

Using of information about actual and expected conditions of wave swell helps to successfully navigate the most profitable routes, water landing, offshore drilling, effective and safe fishing, sea loading, sporting regattas, etc.

Characteristics of the maximum waves are most important characteristic of sea swell, because these waves are the most dangerous for ships and hydrotechnical structures. Therefore, the efficiency of the swell forecast depends largely on how well predict characteristics of the maximum wave. Note that, the term "forecast" for wind swell is used conventionally to difference retrospective calculations from the daily operational calculations of the meteorological predictions of the wind field.

The main elements of wind waves are: height H, period T, length X, phase speed C, steepness E ridge length L.

In case sea depth is more than half the wavelength, wave elements are independent of the depth. If sea depth is less than half the wavelength, then wave elements are change influenced by seabed. The concept of "deep water" has a relative meaning and is defined by the ratio of depth H and wave length X.

Table 1 data are the basis material of parameters for analysis and making forecast.

Table 1. Wave height depending on wind time

Wind speed	**Wind duration (in hours)**						
	5	**10**	**15**	**20**	**30**	**40**	**50**
10 knots	2.0	2.0	2.0	2.0	2.0	2.0	2.0
15 knots	3.5	4.0	4.5	5.0	5.0	5.0	5.0
20 knots	5.0	7.0	8.0	8.0	8.5	9.0	9.0
30 knots	9.0	13.5	15.5	17.0	18.0	18.5	19.0
40 knots	13.5	21.0	25.0	27.5	31.0	32.0	33.0
50 knots	18.0	29.0	36.0	40.0	46.0	48.0	50.0
60 knots	23.0	37.0	46.0	43.0	61.0	66.0	70.0

The task is to determine the type and dependence parameters of the wave height on the wind duration. Based on the table data where row number corresponds to the column of wind duration that is measured in hours, the charts are drawn (see Fig. 1).

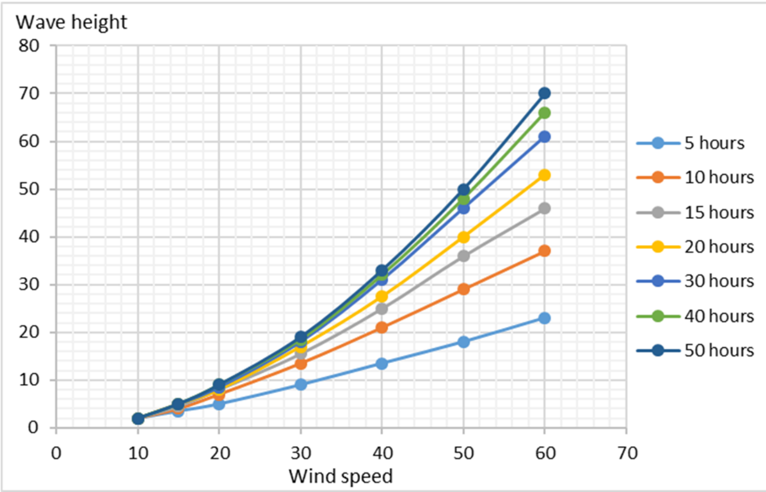

Fig. 1. Dependence of wave height on wind speed and duration

The created scatter chart allows making conclusion that in the wind duration from 5 to 15 hours the dependence can be approximated by linear function; in the wind duration from 20 to 50 hours the dependence will be probably quadratic.

Let us find the dependence parameters which are relevant and evaluate average squared deviation for each of obtained analytic relationships.

Three ways are offered to student for finding the parameters of linear dependency that are determined by the solution of the equations' system (8).

$$\begin{cases} a_0\sum_{i=1}^{n} x_i^2 + a_1\sum_{i=1}^{n} x_i = \sum_{i=1}^{n} x_i y_i \\ a_0\sum_{i=1}^{n} x_i + a_1 \cdot n \;\; = \sum_{i=1}^{n} y_i \end{cases} \tag{8}$$

1. Using Cramer's formulas.

$$a_0 = \frac{n\cdot\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} y_i \sum_{i=1}^{n} x_i}{n\cdot\sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} x_i} \tag{9}$$

$$a_1 = \frac{\sum_{i=1}^{n} x_i^2 \cdot \sum_{i=1}^{n} y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} x_i y_i}{n\cdot\sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} x_i} \tag{10}$$

2. Using Excel's built-in functions SLOPE (parameter a_0) and INTERCEPT (parameter a_1).
3. Using Excel's Solver add-in "Trendline. Linear".
4. The objective of such approach is that student has to, firstly, understand analytic formula, action order, can be possible to calculate by formula; secondly, to use built-in functions and thirdly, to use add-ins.

Performing the calculations show that the results obtained by three different methods match and confirm the hypothesis about linearity of dependences, because the regression coefficients, that are corresponding, R^2 (approximation reliability) are close to 1 (the type of dependence is chosen correctly):

first row (wind duration 5 hours):

$$y = 0{,}423x - 3{,}004;\ R^2 = 0{,}995 \tag{11}$$

second row (wind duration 10 hours):

$$y = 0{,}71x - 6{,}62;\ R^2 = 0{,}9946 \tag{12}$$

third row (wind duration 15 hours):

$$y = 0{,}893x - 9{,}132;\ R^2 = 0{,}9909 \tag{13}$$

Parameters of quadratic dependence $\overline{y} = a_0x^2 + a_1x + a_2$ are determined by system decisions:

$$\begin{cases} a_0\sum_{i=1}^{n} x_i^4 + a_1\sum_{i=1}^{n} x_i^3 + a_2\sum_{i=1}^{n} x_i^2 = \sum_{i=1}^{n} x_i^2 y_i \\ a_0\sum_{i=1}^{n} x_i^3 + a_1\sum_{i=1}^{n} x_i^2 + a_2\sum_{i=1}^{n} x_i = \sum_{i=1}^{n} x_i y_i \\ a_0\sum_{i=1}^{n} x_i^2 + a_1\sum_{i=1}^{n} x_i + a_2 \cdot n = \sum_{i=1}^{n} y_i \end{cases} \tag{14}$$

and are found by matrix method using built-in mathematical functions.

We will remind that system can be presented in matrix form $A\overline{x} = \overline{b}$, where A is the coefficient matrix, $\overline{x}$ is the unknown vector column, $\overline{b}$ is the right part. If A^{-1} is the inverse matrix, then solution of the system has a view $\overline{x} = A^{-1} \cdot \overline{b}$. In our case the parameters of quadratic dependence a_0, a_1, a_2 will be system solution (built-in functions MINVERSE and MMULT are used). Accordantly,

fourth row (wind duration 20 hours:

$$y = 0{,}0115x^2 + 0{,}2714x - 1{,}7868;\ R^2 = 0{,}9998 \tag{15}$$

fifth row (wind duration 30 hours):

$$y = 0{,}0115x^2 + 0{,}3945x - 3{,}5319;\ R^2 = 0{,}9992 \quad (16)$$

sixth row (wind duration 40 hours):

$$y = 0{,}0144x^2 + 0{,}2763x - 2{,}3435;\ R^2 = 0{,}9999 \quad (17)$$

seventh row (wind duration 50 hours):

$$y = 0{,}0166x^2 + 0{,}2013x - 1{,}7246;\ R^2 = 1 \quad (18)$$

Applying the obtained equations (analytical dependencies), it is possible to make a wave height forecast for any wind duration and actually any wind speed.

An expert review of the proposed material was conducted to support expedience of teaching "Data analysis and forecasting" of the course "Information Technologies" on example of math modelling of wave height forecasting in depended on some nature factors and also of the adequacy of the built model to the real conditions. For it, the Method of Expert Estimations (or Delphi method) has been used. This method is the following: expert group was requested to review the work, evaluate its professional direction, reply to the questionnaire and draw conclusions about actuality of the proposed study and the practical application of the obtained results.

The method is used for obtaining quantitative assessment of quality characteristics, parameters and features. Analysis of expert estimations involves each expert completing an appropriate questionnaire, which will help to obtain an objective analysis of the problem and to develop possible solutions [12].

A group involved to work was consisted of marine industry specialists, chief officers and sea captains who works at the academy or undergoes retraining and has extensive experience on the ships. The twelve persons were invited for expert evaluation in a total. The authors took into account such factors as competence, constructive thinking, attitude to work as an expert when form expert group.

The purpose of expert estimation is an establishing of efficiency index (quality) compliance of the proposed method of authenticity solving the real situation.

To confirm or contradict the research conclusions, we used the following forms of conducting and processing expert evaluations:

1. Determining experts' competence and forming of expert commission composition.
2. Construction of the quality weighting coefficients ranking.
3. Parameterization of quality indicators.
4. Conducting expert quality assessment.

Study of the adequacy of obtained examination results.

Expertise of computer modelling method efficiency when analysing natural phenomena should take into account cognitive, software and technological, psychological and pedagogical features.

The expert questionnaire consisted of 16 questions, 12 experts took part in the survey. A quality indicator is number parameter which determines evaluation of the method according to its qualitative characteristics, 5-Point Likert Scale [1] was used for this.

For example, there is a table 2, which contains several questions.

Table 2. (Questionnaire fragment) Quality parameters and their weighting coefficients

No	Name of quality	Qualitative parameters	Weighting coefficient
1	Compliance with the STCW Convention, IMO Model Courses, requirements of the Shipping Register of Ukraine	Full Lack of full No	5 3 1
2	Completeness of the proposed method for solving the problem	Full Lack of full Average Below average Low	5 4 3 2 1
3	Feasibility of using mathematical modelling methods in teaching IT discipline	Full Lack of full Average Below average Low	5 4 3 2 1
4	Feasibility of using methods of mathematical modelling of wave height forecasting depending on certain natural factors	High Average Low	5 3 1
5	Adequacy of built model to the real process	Yes Partly No	5 3 0
6	Efficiency of computer-assisted processing of observation results	Quality Above average Average Below average Low-quality	5 4 3 2 1

The expert evaluation of method efficiency will only be reliable if expert responses are agreed, and concordance method will be used for this purpose.

When measuring the ordinal scale by the ranking method, the purpose of processing the individual expert assessments is construction of generalized objects' order based on the averaging their assessments.

Using questionnaire data the summary rank matrix has been compiled (Table 3).

Table 3. Types of criteria

Expert	Types of criteria															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	3	8	13	4	7	2	6	9	5	12	10	11	16	14	15	1
2	4	10	11	6	8	2	3	5	7	12	9	13	14	15	16	1
3	3	10	12	7	8	2	6	4	5	11	9	13	14	15	16	1
4	4	7	10	6	8	2	5	3	9	12	11	14	13	15	16	1
5	2	10	14	9	8	3	12	4	5	6	7	11	13	15	16	1

Expert	Types of criteria															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
6	3	9	10	8	7	2	6	4	5	11	12	14	15	13	16	1
7	2	12	11	8	10	5	4	3	7	13	6	9	14	15	16	1
8	2	11	14	7	9	4	5	3	6	12	8	10	13	15	16	1
9	2	11	14	4	8	9	10	5	6	16	3	7	12	13	15	1
10	2	5	13	8	7	3	6	4	10	11	9	12	16	14	15	1
11	2	11	12	6	10	5	4	3	8	13	7	9	14	15	16	1
12	2	9	11	7	8	3	4	5	6	10	12	13	14	15	16	1
Δ_i	-71	11	43	-22	-4	-60	-31	-50	-23	37	1	34	66	72	87	-90
S_i	5041	121	1849	484	16	3600	961	2500	529	1369	1	1156	4356	5184	7569	8100

Let us calculate the concordance coefficient by formula:

$$W = \frac{12S}{m^2(n^3 - n)} \tag{19}$$

Computed by the formula (19) coefficient W = 0,875 is closer to one (concordance coefficient can vary from 0 to 1), so we can consider that the experts' answers are agreed.

Let us calculate the Pearson matching criterion to evaluate the significance of concordance coefficient:

$$\chi_W^2 = \frac{12S}{m \cdot n \cdot (n+1)} = 157{,}49 \tag{20}$$

Calculated criterion χ^2 is comparable to the table value for number of degrees of freedom $K = n - 1$ = 16 – 1 = 15 and at the specified significance level α = 0,05.

Conclusions of expert commission. Since χ^2 calculated is 157,49 that is greater than or equal to critical (24,99579), so W = 0,875 is non-random value, therefore the experts' conclusions confirm the practical significance of the results obtained in the article and practicability of their use for further research.

4 Conclusions and directions for further research

A professional navigator, a specialist with advanced training, who claims an officer's position on a ship, has to know not only all the details of navigation and sailing directions, ship's construction, has skills to work with crew and so on. The navigator is responsible for safety of navigation, safety of the ship, crew and cargo. So, he has to follow the instructions of the coastguard controlling the ship's movement, but to analyze the current situation and forecast the consequences of his decisions.

The aim of the discipline "Information Technologies" is studying of the mathematical (computer) modelling method, its application in various subject areas, as well as ability to predict and analyse the results of obtained decisions. In other words, the discipline lays one more necessary brick in the formation of competencies set of a marine industry specialist.

The learning material of discipline provides that students solve problems formulated in their subject area and related to formalization and further use of computer technologies. Such tasks require considerable time for solving, system approach to development.

In the using of information technologies, students practice skills of development of information models, solution algorithms, evaluating of obtained results. They feel a qualitatively new socially significant level of competence; develop professional qualities of a person.

Significant number of navigational, engineering tasks is reduced to the solving of the equations (inequations), the system of equations (system inequations), differential equations or systems, calculating the integrals described objects or phenomena. Using of mathematical (information) modelling methods, forecasting of decision-making results in various activities demand specialists to mastery of the appropriate mathematical apparatus.

References

1. 5-Point Likert Scale. In: Preedy, V.R., Watson, R.R. (eds.) Handbook of Disease Burdens and Quality of Life Measures. Springer, New York (2010). doi:10.1007/978-0-387-78665-0_6363
2. Abuziarov, Z.K., Dumanskaia, I.O., Nesterov, E.S.: Operativnoe okeanograficheskoe obsluzhivanie (Operational oceanographic services). IG–SOTCIN, Moscow (2009)
3. Abuziarov, Z.K., Kudriavaia, K.I., Seriakov, E.I., Skriptunova, L.I.: Morskie prognozy (Marine Forecasting), 2nd edn. Gidrometeoizdat, Leningrad (1988)
4. Bilousova, L.I., Kolgatin, O.H., Kolgatina, L.S.: Computer Simulation as a Method of Learning Research in Computational Mathematics. CEUR Workshop Proceedings **2393**, 880–894 (2019)
5. Chapra, S.C., Canale, R.P.: Numerical Methods for Engineers, 7th edn. McGraw Hill Education, New York (2017)
6. El-Gebeily, M.A., Yushau, B.: Numerical Methods with MS Excel. The Montana Mathematics Enthusiast **4**(1), pp. 84–92 (2007)
7. Ewing, J.A.: A numerical wave prediction model for the North Atlantic Ocean. Deutsche Hydrographische Zeitschrift **24**, 241–261 (1971). doi:10.1007/BF02225707
8. Flehantov, L., Ovsiienko, Yu.: The Simultaneous Use of Excel and GeoGebra to Training the Basics of Mathematical Modeling. CEUR Workshop Proceedings **2393**, 864–879 (2019)
9. Hoffman, J.D.: Numerical Methods for Scientists and Engineers, 2nd edn. CRC Press, Boca Raton (2001)
10. Khain, A.P. Matematicheskoe modelirovanie tropicheskikh tciklonov (Mathematical modeling of tropical cyclones). Gidrometeoizdat, Leningrad (1984)
11. Kozlovsky, E.O., Kravtsov, H.M.: Multimedia virtual laboratory for physics in the distance learning. CEUR Workshop Proceedings **2168**, 42–53 (2018)
12. Kravtsov, H.: Methods and Technologies for the Quality Monitoring of Electronic Educational Resources. CEUR Workshop Proceedings **1356**, 311–325 (2015)

13. Kudriavaia, K.I., Seriakov, E.I., Skriptunova, L. I.: Morskie gidrologicheskie prognozy (Marine hydrological forecasts). Gidrometeoizdat, Leningrad (1974)
14. Lavrenov, I.V.: Matematicheskoe modelirovanie vetrovykh voln v prostranstvenno-neodnorodnom okeane (Mathematical modeling of wind waves in a spatially heterogeneous ocean). Hydrometeoizdat, St. Petersburg (1998)
15. Markova, O., Semerikov, S., Popel, M.: CoCalc as a Learning Tool for Neural Network Simulation in the Special Course "Foundations of Mathematic Informatics". CEUR Workshop Proceedings **2104**, 338–403 (2018)
16. Merzlykin, P.V., Popel, M.V., Shokaliuk, S.V.: Services of SageMathCloud environment and their didactic potential in learning of informatics and mathematical disciplines. CEUR Workshop Proceedings **2168**, 13–19 (2018)
17. Modlo, Ye.O., Semerikov, S.O., Bondarevskyi, S.L., Tolmachev, S.T., Markova, O.M., Nechypurenko, P.P.: Methods of using mobile Internet devices in the formation of the general scientific component of bachelor in electromechanics competency in modeling of technical objects. CEUR Workshop Proceedings **2547**, 217–240 (2020)
18. Modlo, Ye.O., Semerikov, S.O., Nechypurenko, P.P., Bondarevskyi, S.L., Bondarevska, O.M., Tolmachev, S.T.: The use of mobile Internet devices in the formation of ICT component of bachelors in electromechanics competency in modeling of technical objects. CEUR Workshop Proceedings **2433**, 413–428 (2019)
19. Nesterov, E.S.: Operativnye sistemy prognoza parametrov morskoi sredy dlia evropeiskikh morei (Operational systems for predicting the parameters of the marine environment for European seas) // Meteorologiia i gidrologiia 1, 121–126 (2005)
20. Pfeiffer, K.D.: Ein dreidimensionales Wartmodell. GKSS-Bericht Nr.85, Geesrhacht (1985)
21. Piterbarg, L.I.: Dinamika i prognoz krupnomasshtabnykh anomalii temperatury poverkhnosti okeana (stat. podkhod) (Dynamics and forecast of large-scale anomalies in ocean surface temperature (statistical approach)). Gidrometeoizdat, Leningrad (1989)
22. Samchynska, Y., Vinnyk, M.: Decision Making in Information Technologies Governance of Companies. CEUR Workshop Proceedings **1844**, 96–110 (2017)
23. Semerikov, S.O., Teplytskyi, I.O., Yechkalo, Yu.V., Kiv, A.E.: Computer Simulation of Neural Networks Using Spreadsheets: The Dawn of the Age of Camelot. CEUR Workshop Proceedings **2257**, 122–147 (2018)
24. Semerikov, S.O., Teplytskyi, I.O., Yechkalo, Yu.V., Markova, O.M., Soloviev, V.N., Kiv, A.E.: Computer Simulation of Neural Networks Using Spreadsheets: Dr. Anderson, Welcome Back. CEUR Workshop Proceedings **2393**, 833–848 (2019)
25. Shuleikin, V.V.: Raschet razvitiia, dvizheniia i zatukhaniia tropicheskikh uraganov i glavnykh voln, sozdavaemykh uraganami (Calculation of the development, movement and attenuation of tropical hurricanes and major waves created by hurricanes). Hydrometeoizdat, Leningrad (1978)
26. Shyshkina, M.P., Kohut, U.P., Popel, M.V.: The Systems of Computer Mathematics in the Cloud-Based Learning Environment of the Educational Institutions. CEUR Workshop Proceedings **1844**, 396–405 (2017)
27. Zaytseva, T., Kravtsova, L., Puliaieva, A.: Computer Modelling of Educational Process as the Way to Modern Learning Technologies. CEUR Workshop Proceedings **2393**, 849–863 (2019)