CHOICE OF SHIP MANAGEMENT STRATEGY BASED ON DATA ANALYSIS

Tatyana Zaytseva✉, Nataliia Kaminska✉

Kherson State Maritime Academy, Ukraine

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Abstract

These theses focus 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 behavior, which surrounds a ship. Since solving problems of analysis and forecasting involves the use of mathematics, the study of this topic within the discipline "Information Technology in Professional Activities" takes place using the capabilities of spreadsheets, supported by mathematical methods for constructing regression equations and solving systems of algebraic equations. The use of mathematical modeling apparatus allows students to solve such problems. The using of mathematical modelling apparatus allows students to be able to solve such tasks.

The general problem statement and its actuality

Forecasting of natural phenomena that have different, both positive and negative influence on the strategy of ships using is an 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 in Professional Activities". The purpose of studying of the course material is 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 fore-casting" 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 behavior.

Actuality of the research

Foreign researchers have made a great contribution to analysis and fore-casting of processes that affect to safe navigation (J. A. Ewing [1], K. D. Pfeiffer [2] and others).

Fundamentals of numerical methods for solving problems are published in scientific and educational publications by famous authors: J. Hoffman. [3], S. Chapra [4], S. Semerikov [5]. 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 El-Gebeily [6] and the authors of this theses.

Problems of introduction of computer modelling in the study of informatics disciplines paid attention to foreign and Ukrainian specialists V. Kukharenko, O. Rybalko, O. Markovich [7].

Modern operative oceanography develops by way of uniting many countries efforts. International projects involving Germany, Italy, Portugal, and the Netherlands are being successfully implemented. Understanding of this way's importance in study world ocean allows developing scientific research work that result is an improvement ship coordination and disaster prevention systems to ensure safe.

Solving basic problems

Hydrometeorological conditions 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 most range 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 so as all process factors that are unknown. Further, as a rule, the forecasting methods are based on the use of discrete values characteristics, also brings a certain error in the study results of this process.

Statistical methods of forecast provide an opportunity to evaluate the development of hydrometeorological 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 for 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 pattern between phenomena is 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 right decision when choosing the number of predictors is greatly facilitated develop of forecast method and ensures increased the reliability of operational forecasts.

At the second stage of development forecast methodology general physical regularity that was previously identified applies to specific physical and geographical sea conditions. For this purpose, observational data that needed for develop of method are carefully analyzed for representativeness and comparability of observations in different years.

At the third stage are beginning to quantitative prognostic relationships. 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 type of its dependency. A detailed cases' analysis that deviates should be made and ascertain 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.

Next stage is the choice of the most adequate mathematical apparatus, which would allow the best approach to the problem, i.e. creation of a reliable forecast method.

Hydrodynamics forecast method is 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. Example, for Southern Hemisphere when describe physical process in the ocean such turbulent liquid thermodynamics equations can be accepted:

for moving

$$\frac{du}{d\tau} = -\frac{1}{p}\frac{\partial p}{\partial x} + f\nu + \frac{\partial}{\partial z}k'\frac{\partial u}{\partial z}, \tag{1}$$

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

$$\frac{\partial p}{\partial z} = g\rho; \tag{3}$$

for continuity

$$div_h u + \frac{\partial \omega}{\partial z} = 0; \tag{4}$$

for heat distribution

$$\frac{\partial t_\omega}{\partial \tau} + u \cdot grad_h t_\omega + \omega\frac{\partial t_\omega}{\partial z} = \frac{\partial}{\partial z}k_{t_\omega}\frac{\partial t_\omega}{\partial z} + \sum Q; \tag{5}$$

for salt distribution

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

for state of sea water

$$\rho = \rho\left(t_\omega, S, P_\omega\right), \tag{7}$$

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

Most simple way to objectively realization information that based on statistical observations for forecast of ocean phenomena is a constructing 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 well characteristic of links in such systems.

Functional depending 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. However, in practice, as rule, have not dealt with functional dependencies, but of statistical ones. In this case, to each value of one quantity corresponds many possible values of other quantity. Dispersing of possible values explains by influence of many additional factors, which usually neglected when link between quantities is studied. A dimensionless correlation coefficient characterizes of dependency measure between quantities in a linear regression, that in absolute value no more than one: *abs(r)<=1*.

Correlation coefficient equals zero for independence quantities *X* and *Y*. Equality of correlation coefficient to zero means that linear dependence is absent (but does not eliminate nonlinear dependence). Other correlation methods are used in nonlinear link. The closer is absolute value of the correlation coefficient to one, the closely is the linear dependence between the quantity. 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 to significant simplify the calculation by selecting a convenient starting point (X_0, Y_0) and corresponding units of scale. Correlation coefficient and regression equation for both variables can be found approximately from the correlation chart, and more accurately – by method of least squares.

Consider a typical task of wave height forecasting depending on wind speed and the duration of its effects (forecasts of wind waves). The main elements of wind waves are height *h*, period *T*, length *X*, phase speed c, steepness e, ridge length *L*. If 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 wavelength *X*.

The task is to determine the type and dependency parameters of the wave height on the wind duration. Based on the experimental data the charts are drawn (fig. 1).

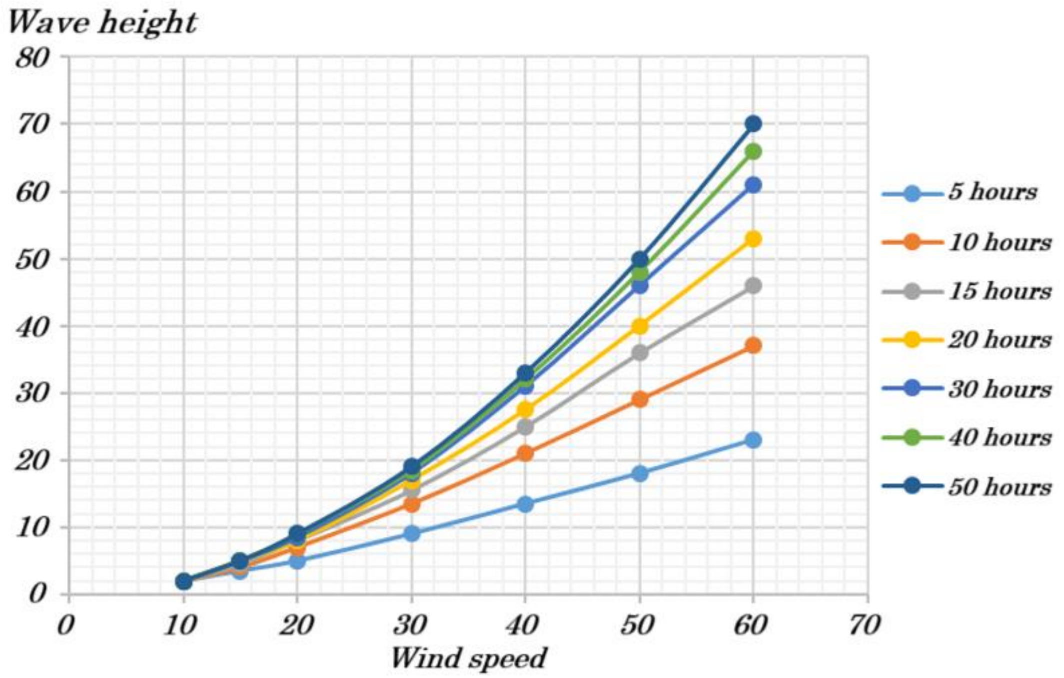

Figure 1. *Dependence of wave height on wind speed and duration*

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.

Next, you can find the parameters of the corresponding dependencies and estimate the standard deviation for each of the obtained analytical relationships.

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

first row (wind duration 5 hours):

$$y = 0{,}423x - 3{,}004;\ R^2 = 0{,}995; \qquad (8)$$

second row (wind duration 10 hours):

$$y = 0{,}71x - 6{,}62;\ R^2 = 0{,}9946; \qquad (9)$$

third row (wind duration 15 hours):

$$y = 0{,}893x - 9{,}132;\ R^2 = 0{,}9909. \qquad (10)$$

Parameters of quadratic dependence $\overline{y} = a_0 x^2 + a_1 x + a_2$ are determined by system decisions.

$$\begin{cases} a_0 \sum_{i=1}^{n} x_i^4 + a_1 \sum_{i=1}^{n} x_i^3 + a_2 \sum_{i=1}^{n} x_i^2 = \sum_{i=1}^{n} x_i^2 y_i, \\ a_0 \sum_{i=1}^{n} x_i^3 + a_1 \sum_{i=1}^{n} x_i^2 + a_2 \sum_{i=1}^{n} x_i = \sum_{i=1}^{n} x_i y_i, \\ a_0 \sum_{i=1}^{n} x_i^2 + a_1 \sum_{i=1}^{n} x_i + a_2 \cdot n = \sum_{i=1}^{n} y_i, \end{cases} \qquad (11)$$

are found in the matrix method using built-in Excel mathematical functions.

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

Conclusions

The aim of the discipline "Information Technologies in Professional Activities" is studying of the mathematical (computer) modelling method, its application in various subject areas, as well as ability to predict and analyze the results of obtained decisions.

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 and 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]. Ewing, J.A.: A numerical wave prediction model for the North Atlantic Ocean. Ocean Dynamics 24, 241–261, https://link.springer.com/article/10.1007/BF02225707.

[2]. Pfeiffer, K.D.: Ein dreidimensionales Wattmodel. GKSS Forschungszentrum Geesthacht GMBH. Geesthacht (1995).

[3]. Hoffman, J.: Numerical Methods for Scientists and Engineers. 2nd edn. New York, https://epiportal.com/Ebooks/Numerical%20Methods%20for%20Engineers%20and%20Scientists.pdf.

[4]. Chapra, S., Canale, R.: Numerical Methods for Engineers. McGraw Hill Education. New York, https://www.academia.edu/31722261/Numerical_Methods_for_Engineers_7th_Edition_steven_chapra.

[5]. 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. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 1st International Workshop on Augmented Reality in Education (AREdu 2018), Kryvyi Rih, Ukraine, CEUR Workshop Proceedings, vol. 2257, pp. 122–147.

[6]. El-Gebeily, M., Yushau, B.: Numerical Methods with MS Excel. The Montana Mathematics Enthusiast, vol. 4(1), pp. 84-92, http://scholarworks.umt.edu/cgi/.

[7]. Markovich, O.S.: Computer modeling in educational research: the development of new teaching methods using information technology. Modern problems of science and education. https://science-education.ru/ru/article/view?id=21724 (2015).

Authors' Information

Tatyana Zaytseva, Candidate of Pedagogical Sciences, Associate Professor, Department of Innovative Technologies and Technical Devices of Navigation, Kherson State Maritime Academy, Kherson, Ukraine, ORCID ID: 0000-0001-6780-719X.

Nataliia Kaminska, Teacher, Department of Innovative Technologies and Technical Devices of Navigation, Kherson State Maritime Academy, Kherson, Ukraine, ORCID ID: 0000-0002-9975-7403.