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STUDY OF INTER-SUBJECT RELATIONS IN BIOLOGY BASED ON WOLTER'S MODEL

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ABSTRACT

This article, based on Voltaire's model, explores intersubject connections in biology with subjects related to information technology. For this purpose, the “model-algorithm-program” triad is applied and the dynamics of population change over time is studied.

Keywords: biology, population, prey, predator, mathematical modeling, Euler's method, model, algorithm, program, intersubject connections.

INTRODUCTION

Mathematical modeling is widely used in various branches of science and technology, as well as in the educational process [1-5]. It is very important when studying interdisciplinary relationships. This method of cognition, construction, design combines many advantages of both theory and experiment. The computational experiment consists of five stages.

The first stage is the mathematical formulation of the problem or the choice of a mathematical model.

The second stage is the construction of an approximate (numerical) method for solving the problem, writing a computational algorithm.

The third stage is computer programming of a computational algorithm.

The fourth stage is carrying out calculations on a computer.

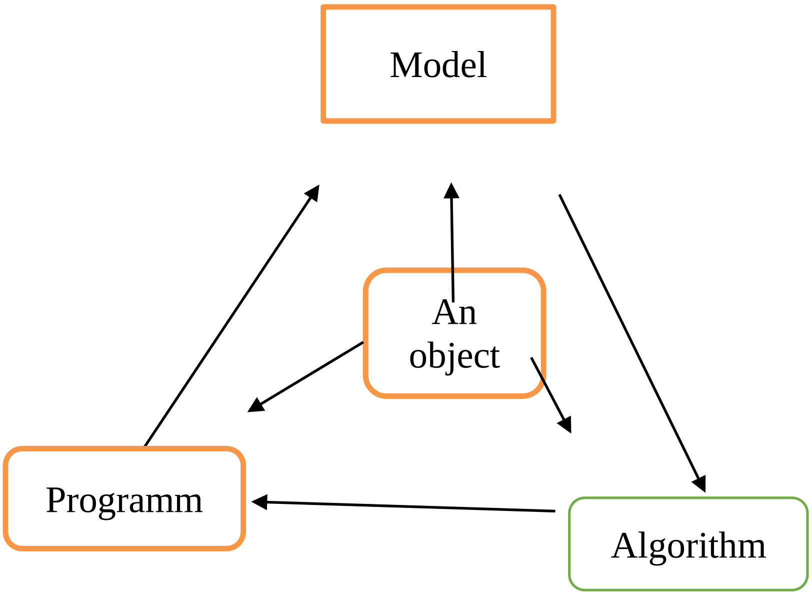
The fifth stage is the analysis of the results obtained and the refinement of the mathematical model.

Computational experiments with models of objects allow, relying on the power of modern computational methods and technical tools of informatics, to study objects in detail and in depth in sufficient completeness, inaccessible to purely theoretical approaches, which is an advantage of the experiment.

At present, mathematical modeling is entering a fundamentally important stage in its development, "embedding" in the structures of the so-called information society [6]. The impressive progress in the means of processing, transmitting and storing information meets the global trends towards the complication and mutual penetration of various spheres of human activity.

Without possession of information "resources" it is impossible even to think about solving the ever larger and more diverse problems facing the world community. However, information as such often gives little for analysis and forecast, for making decisions and monitoring their implementation. We need reliable ways of processing information "raw materials" into a finished "product", i.e. into exact knowledge. The history of the methodology of mathematical modeling convinces: it can and should be the intellectual core of information technology, the entire process of informatization of society.

Technical, ecological, economic and other systems studied by modern science no longer lend themselves to research (in the required completeness and accuracy) by conventional theoretical methods. Therefore, mathematical (broader informational) modeling is an inevitable component of scientific and technological progress. Mathematical modeling can be conventionally divided into three stages: model-algorithm-program (see diagram) [6-7].



Having created the “model-algorithm-program” triad, the researcher is given a universal, flexible and inexpensive tool, which is first debugged and tested in “trial” computational experiments.

Let us consider intersubject connections in biology with information technologies based on the "model-algorithm-program" triad using a specific example of the "predator-prey" system. For this purpose, let us consider the model of the relationship "predator-prey" (Voltaire's model) [7]. The dynamics of the population size, that is, the change in the number of prey, entails a change in the number of predators, since the population lives in interaction. The mathematical model of the simplest two-species predator-prey system is based on the following assumptions:

1. The population size of prey N and predators M are only functions of time, i.e. $N(t),\ M(t)$;
2. In the absence of interaction, the number of species changes according to the Malthus model, while the number of predators decreases and the number of prey increases, i.e.

$$\frac{dN}{dt}=\alpha N,\quad \frac{dM}{dt}=-\beta M,\quad \alpha>0,\ \beta>0;$$

3. Natural changes are considered insignificant;

4. The growth rate of the number of prey changes in proportion to the number of predators, i.e. magnitude cM, $c>0$, and the growth rate of predators increases in proportion to the number of prey, i.e., fN, $f>0$, then, we obtain the system of Voltaire equations [6-7].

$$\begin{cases} \dfrac{dN}{dt} = (\alpha - cM)N \\ \dfrac{dM}{dt} = (-\beta + fN)M \end{cases} \tag{1}$$

System (1) is reduced to a form that can be applied by numerical methods

$$\begin{cases} \dfrac{dN(t)}{dt} = (\alpha - cM(t)N(t), \\ \dfrac{dM(t)}{dt} = (-\beta + fN(t))M(t), \end{cases} \quad 0 < t \le T \tag{1'}$$

$N(0)=N_0$, $M(0)=M_0$ где N_0, M_0 - are set, as well as the values of the parameters are set: α, β, c, f. On the segment [0, T], we introduce the grid $\varpi_h = \{t_j = j*\tau, j = 0,1,\dots,K, \tau = T/K\}$, where K-is a given integer.

To solve system (1 '), we use the Euler method: [8]:

$$\begin{cases} \dfrac{N^{j+1} - N^j}{\tau} = (\alpha - c*M^j)*N^j, \\ \dfrac{N^{j+1} - N^j}{\tau} = (-\beta + f*N^j)*M^j, \end{cases} \quad j = 0,1,\dots.K-1, \tag{3}$$

where τ-grid step, $N^{j+1} = N(t_{j+1})$, $N^j = N(t_j)$, $M^{j+1} = M(t_{j+1})$, $M^j = M(t_j)$. Discrete system (3) is reduced to the form

$$\begin{cases} N^{j+1} = N^j + \tau(\alpha - c*M^j)*N^j, \\ M^{j+1} = M^j + \tau(-\beta + f*N^j)*M^j, \; j = 0,1,\dots., K-1. \end{cases} \tag{4}$$

here $N^0 = N_0$, $M^0 = M_0$ set values. By solving system (4), the population of prey and predators is found at different points in time. For this purpose, we will compose an algorithm for solving problem (1) on the dynamics of the population size:

1) parameter values are determined α, β, c, f and initial values N_0, M_0;
2) a grid is introduced on the segment [0, T]; this segment is divided into K parts;
3) the values are calculated N^{j+1}, M^{j+1} at a new time step using the formula (4).

Compiled and debugged a computer program in the C ++ language to solve the problem. The solution to the population problem demonstrates intersubject connections between the subjects of biology, mathematical modeling, numerical methods, theory of algorithms, programming and information technology.

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