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Conducting a Computational Experiment using Test Functions

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Abstract:

This article discusses the stages of the computational experiment, the network nodes, the problem of finding solutions to complex problems using test functions. The calculation of the differential problem using test functions is illustrated by examples.

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Introduction

The technology of conducting computational experiments is important for specialists in applied mathematics. At present, a new method of studying complex processes, which belongs to mathematical description or mathematical modeling, has emerged - the computational experiment, that is, the study of real processes through computational mathematics.

Main Part

The process of conducting a computational experiment is carried out in several stages:

In the *first* stage, the problem is interpreted mathematically or a mathematical model is chosen. Until then, it will be necessary to carry out a physical approximation, i.e. to determine which factors can be involved and which can be ignored. A mathematical model consists of equations that interconnect a group of sought quantities and a group of given quantities. These can be equations or differential equations, the writing of which with all the necessary data (e.g., about the coefficients of the equation, about the initial and boundary conditions) is a matter of choosing a mathematical model.

In the *second* stage, an approximate (numerical) method for solving the problem is created, the calculation algorithm is written.

In the *third* stage, numerical calculations are performed on the computer.

In the *fourth* step, the numerical results obtained are analyzed and the mathematical model is determined.

Sometimes the mathematical model can be very rough, i.e. the calculation results may not match the results of the physical experiment. Or the model will be too complex and the solution to the problem can be obtained with sufficient accuracy through other simpler models. In this case, starting from the first stage of the work calculation experiment, all the steps will have to be repeated again, and so on.

A computational experiment is not a one-time calculation using standard formulas, but rather, it involves performing a series of calculations with different mathematical models. For example, it is necessary to determine the optimal condition of a chemical process, that is, to determine the conditions under which the chemical reaction is most rapid. The solution to this problem depends on a number of parameters (e.g., temperature, pressure, composition of the reacting mixture, etc.). To find the optimal mode of the reaction, it is necessary to perform a series of calculations at different values of these parameters, that is, to perform several options.

In practice, discrete mathematical models — for the experimental verification of differential circuits — are often used by minimizing the network nodes. However, qualitative analysis of differential circuits by shrinking network nodes can lead to erroneous conclusions. Therefore, it is recommended to use the method of narrowing the nodes with some caution.

The method of test functions can be used to study the approximation and order of precision of discrete mathematical models.

In the method of test functions, any function is selected, this function is chosen arbitrarily, and this function is conditioned that the coefficients of the equation satisfy the conditions of continuity at the breaking point. The test function is placed in the basic differential equation and the function to its right is found and the boundary conditions are determined. The generated problem is solved using a discrete mathematical model and the obtained numerical solution is compared in different networks with the selected test function.

We now consider the application of the test function method to a specific problem. For simplicity, we consider the following differential problem

$$u''(x) = -f(x), \qquad 0 < x < 1, \tag{1}$$

$$u(0) = \mu_1, \qquad u(1) = \mu_2 \tag{2}$$

We put the following discrete problem corresponding to the differential problem (1)-(2):

$$\frac{y_{i-1} - 2y_i + y_{i+1}}{h^2} = -\varphi_i, \qquad 0 < i < M, \tag{3}$$

$$y_0 = \mu_1, \;\; y_M = \mu_2, \tag{4}$$

here $y_i = y(x_i), \;\; \varphi_i = f(x_i),$ and in the cut [0,1]

$$\varpi_h = \{x_i = ih, \;\; i = 0,1,2,..., M, h = 1/M\}$$

a separate grid is included. The difference problem (3) - (4) is solved by the progonka method and the values of the difference solution y_i are found at the internal nodes of the network ϖ_h.

We use the method of test functions to study the differential problem (1) - (2) by means of a computational experiment. To do this, as a solution to this problem, that is, as a test function, we choose the following function (it is optional):

$$u(x) = e^{Ax}, \tag{5}$$

where A is an arbitrary parameter. We put the differential problem (1) - (2) corresponding to the test function (5):

$$u'(x) = Ae^{Ax},$$

$$u''(x) = A^2 e^{Ax}$$

In this situation, it will be $f(x) = -A^2 e^{Ax}$, and the boundary conditions will take the following form:

$$u(0) = \mu_1 = e^{A \cdot 0} = 1,$$

$$u(1) = \mu_2 = e^{A \cdot 1} = e^A,$$

The difference problem (3) - (4) has the following appearance for the selected test function:

$$\frac{y_{i-1} - 2y_i + y_{i+1}}{h^2} = -\varphi_i, \qquad 0 < i < M, \tag{6}$$

$$y_0 = 1, \quad y_M = e^A, \tag{7}$$

$$\varphi_i = f(x_i) = -A^2 e^{Ax_i},$$

$$x_i = ih$$

Then the difference problem (6), (7) is solved on the computer by the progonka method and the values of the difference solution

$y_i = y(x_i)$ in the network nodes are determined. It is in these network nodes that the values of the selected test function

$$u_i = u(x_i) = e^{Ax_i} = e^{A \cdot ih}$$

are also calculated. The resulting differential solution y_i is compared with the value of the test function u_i. Улар If these are close to each other with $o(h^2)$ accuracy, then the selected discrete model, its algorithm and computer program will be implemented correctly. Otherwise, some errors or omissions will be made in the discrete model, algorithm, or computer program. As a result of their complete elimination, the difference between the discrete solution and the values of the selected test function at the network nodes is ensured. Thus the commonality of the continuous mathematical model (1) - (2) and the discrete model (3), (4) is ensured. Then, based on this discrete model, algorithm and program, it will be possible to solve the continuous model (1), (2) numerically with arbitrary right-hand function $f(x)$ and boundary conditions $\mu_1(x), \mu_2(x)$.

Conclusion

The test function method allows the study of the mutual adequacy of a discrete model, algorithm, and computer program. The method of test functions can be used to study large classes of simple and special derivative equations.

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