INTELLIGENT COMPUTERS - THE EFFECTIVE MEANS FOR THE INVESTIGATION AND SOLUTION OF SCIENTIFIC AND TECHNICAL PROBLEMS

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1. Computational machinery is a basis of the scientific and technical progress of a society. Computers designed for solving scientific and technical problems should be very productive and be able to process large volumes of information. These requirements stimulate the development of super-computers and workstations.

Do we make use of all the possibilities of computers intended for scientific and technical problems? To answer this question, let us consider a traditional scheme of posing and solving scientific and technical problems [1,2].

Let it is necessary to solve an application problem describing a behaviour of a construction's element. Depending on the conditions of work of the element , this problem can be described by a group of physical models. The principle difference between an application problem and a physical model is that physical model investigates an effect of only one factor, while in the application problem all the factors on which the solution of application problem depends, act simultaneously. The error in the presentation of initial data takes into account the effect of the rest of factors .

A physical model can be described by means of mathematical language. As a rule , the physical and, hence, the mathematical model have approximately given input data. As it is known, the mathematical model is described in the terms of functions, operators, functionals, etc. For solving the mathematical problems on computer they should be a priori „arithmetized". As usual, the discretization of problems is implemented by means of numerical methods of solution, such as the finite elements method, the finite differences method, etc. Hence, instead of the mathematical model a discrete model of the problem arises. After the input of data on the discrete model into computer and their conversions from decimal into machine number system, the computer already contains the machine model of the problem. A technical scheme of construction of different models of application problem is presented on fig.1.

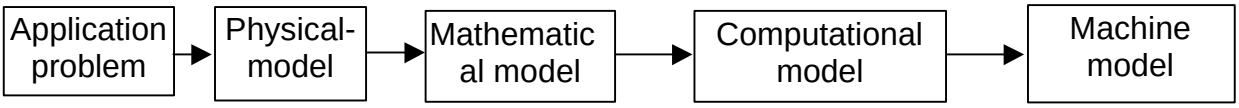


Fig. 1

A solution algorithm is created on the basis of the solution method, but in so doing the properties of the problem being solved should be taken into account. A computational scheme of the problem is constucted on the basis of the solution algorithm with taking into account mathematical and technical characteristics of computer. A program (the computational scheme in terms of programming language) should take into account the characteristical features of the computer, and the program expressed in machine codes and ready for execution realises an algorithm with taking into account the capabilities of

the operating system. The technological scheme of the creation of different-level algorithms is presented on fig.2

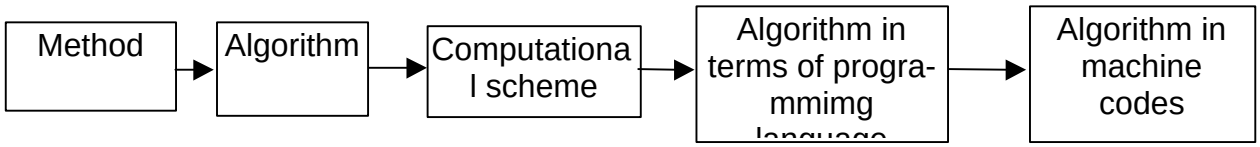


Fig. 2

Thus, when posing a problem on the computer a specialist or a group of specialists should:

- construct a sequence consisting of physical, mathematical and discrete models;
- investigate the properties of each of the models;
- choose or create both the problem's solving algorithm and program with taking into account the properties revealed as well as mathematical and technical peculiarities of computer;
- estimate the reliability of the obtained machine results.

Thus , in the traditional technology of posing and solving scientific and technical problems a user should carry out all the necessary investigations of the problem, to choose or construct an algorithm required for its solution as well as to write a program for its solution in terms of algorithmic language, while the computer compiles this program and realizes it in machine codes by using in the process the data of the machine model, i.e. the computer realizes only two last sequential stages of the technological scheme (fig. 3).

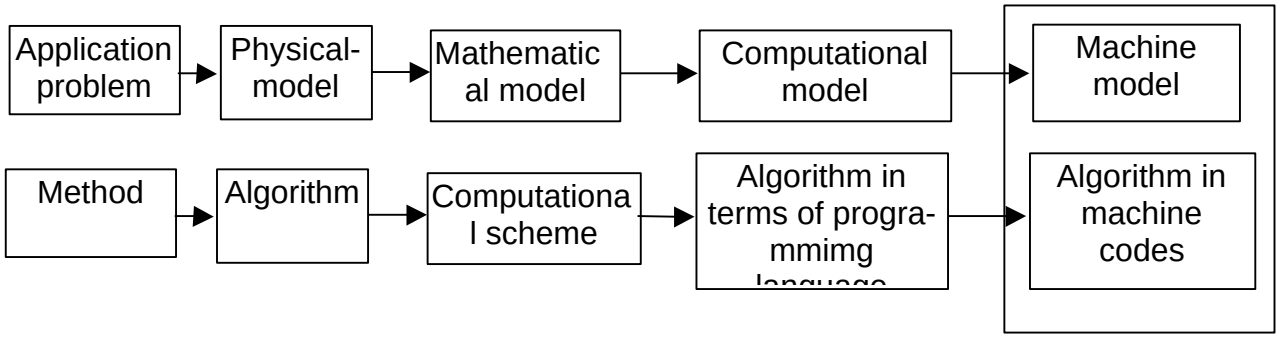


Fig. 3

2. Unfortunately, when solving scientific and research problems in a number cases a solution is obtained not possessing any physical sense [3]. There are several causes of this fact[4]. Let us mention some of them. As a rule, the properties of problems with accurate initial data are investigated, while all application problems have approximately given initial data. Let us demonstate difficulties related to this fact by means of some simplest examples [5, 6, 7]

Two systems of linear algebraic equations

$$\begin{aligned} 100\,x_1 + 500\,x_2\ 0\ 1700 \\ 15\,x_1 + 75.01\,x_2 = 255 \end{aligned} \qquad \begin{aligned} 100\,x_1 + 500\,x_2 = 1700 \\ 15\,x_1 + 75.01\,x_2 = 255.03 \end{aligned}$$

differ in the 5^{th} significant figure , but the first system has a solution

$$x_1 = 17, \qquad x_2 = 0$$

while the second one -

$$x_1 = 2, x_2 = 3$$

The determinant of both systems is equal to 1. Hence, the solutions of both systems exist, are unique and stable. But initial data of the second system are approximately given with respect to the first one. An analogous situation takes place for other classes of problems [5,6,7]

The properties of mathematical and discrete models can differ from the properties of the machine model.

Thus, the system

$$Ax = b,$$

where

$$A = \begin{matrix} 0.1348531574394464 & 0.1878970588235294 & 0.1909117647058824 & 0.1779264705882353 \\ 0.1878970588235294 & 0.262 & 0.265 & 0.247 \\ 0.1909117647058824 & 0.265 & 0.281 & 0.266 \\ 0.1779264705882353 & 0.247 & 0.266 & 0.255 \end{matrix}$$

and

$$b = 0.3516,\ 0.4887,\ 5105,\ 0.4818,$$

theoretically is not singular and has one classic solution

$$x = 6.662...e12,\ -4.016...e12,\ -1.665...e12,\ 9.9797...e11$$

The machine model has the matrix

$$A = \begin{matrix} 0.13485315743944\mathbf{397} & 0.1878970588235\mathbf{389} & 0.190911764705882\mathbf{391} & 0.17792647058823\mathbf{5297} \\ 0.18789705882352\mathbf{389} & 0.26200000000000\mathbf{010} & 0.265\ 000000000000\mathbf{13} & 0.24\mathbf{6999999999999999}\ , \\ 0.190911764705882\mathbf{391} & 0.265000000000000\mathbf{13} & 0.281000000000000\mathbf{27} & 0.266000000000000\mathbf{14} \\ 0.17792647058823\mathbf{5297} & 0.246999999999999\mathbf{97} & 0.266000000000000\mathbf{14} & 0.255000000000000\mathbf{004} \end{matrix}$$

and the exact solution

$$x = 3.547...e12,\ -2.138...e12,\ -8.867...e12,\ 5.216...e11$$

However, by investigating the discrete model a user extends its properties to the machine model that is not always done on legal grounds, as one can see from above.

Besides , the computer arithmetic differes from the arithmetic the people deal with [1,4]:

- the continuum of all real numbers in the computer is approximated by a finite set of finite factors (even when inputing numerical data, the round-off errors occur);
- the phenomenon of the „ machine zero“ generates a number of difficulties in the realization of computational algorithms (any modern computer possesses the least positive number which can be represented in it ; all numbers less than this number by the absolute value replaced by zero);
- the computer’s arithmetic operations differ from mathematical ones: the associativity and distributivity laws don’t hold, while the commutativity law in the floating-point arithmetic holds only for the correct round-off procedure.

The influence of both the computer arithmetic and compilers can be seen on the example of solving the system of linear algebraic equationspresented above by Bunch method by means of the LINPACK's FORTRAN-program[8]:

$$x_{BUNCH} = 2.810...e12,\ \ -1.694...e12,...-7.027...e11,\ \ 4.133...e11,$$

as well as by Gauss method by means of the C-program from [9] :

$$x_{Gauss} = 3.164...e12,\ \ -1.908...e12,...-7.911...e11,\ \ 4.653...e11$$

3. An intelligent software as well as intelligent computers, an architecture of which supports these intelligent software, enable to solve the problem of investigating and solving the machine models of scientific and technical problems with approximately given initial data. Intelligent application programs as well as intelligent programs are the components of the intelligent software.

Under the intelligent software for solving the class of scientific and technical problems with approximately given initial data we shall mean a complex of programs enabling to formulate a problem in terms of a subject area, to automatically investigate the properties of the machine model of problem, in accordance with these revealed properties to automatically construct an algorithm and to synthsize a program with taking into account both structure and architecture of computers; to solve the problem; to estimate the reliability of the solution as well as to visualize the obtained results in terms of subject area.

It is natural that a full analyzis of a problem's properties requires an additional time for its computer realization and it is not reasonable to carry it out every time. That is why it is enough to carry these investigations out for the problems of the same nature and then to use libraries of intelligent programs for massive computations [2] .

Under the intelligent program we shall mean a program which in the course of a problem's solving checks an accordance of the solution algorithm with the properties of a machine model of the problem, solves the problem and estimates the reliability of the solution.

Program for the problem's investigation and solution can be designed in the form of an intelligent interface.

An intelligent interface comprises a dialogue system, planning and control systems, knowledge base on the application area containing programs for problem's investigation and solution, as well as means for estimating the reliability of the obtained results.

The intelligent software supports an information computing technology of solving scientific and technical problems [10,11]

An intelligent computer implements:

- a possibility of the end user's communication with computer by means of formalized language of the subject area, including the communication by means of audio and video facilities,
- the utilization of algorithms for making a decision based on the investigation of the problem along with explanation of these solutions on the basis of inaccurate or incomplete information given by the user;
- a possibility to manipulate the knowledge;
- application of algorithms for the analysis of the solutions obtained;
- the utilization of both retrieval procedures and methods for solving search problems related to the necessity to look for and to look through the great number of variants;
- the application of linquistical methods for the generation and computer translation of texts, etc.

– the modelling of creative processes occuring in different fields of the human activity;
– a possibility of a dynamic spacial visualization for the results' representation [12]

Thus, within the information computing technology for both the investigation and solution of scientific and technical problems an intelligent computer realizes three last stages depicted on fig.1 as well as four last stages on fig.2. Thus, as one can see, the utilization of the intelligent computer considerably redistributes the volume of work between a user and computer (see fig. 4).

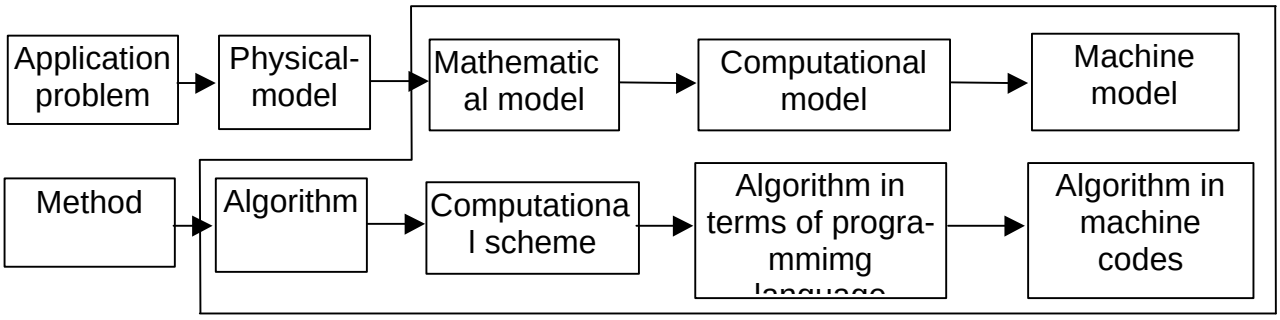


Fig. 4

An experience gained in the utilization of components of machine intelligent environment on computers of different classes enables to 10-100 times reduce the time needed for the posing and solving of problems by the end user.

4. Intelligent computers undertake investigation of the properties of problems by creating the comfortable conditions for the end user and in so doing by reducing the time required for posing and solving problems, moreover they significantly reduce the time required for solving the problem at the expense of both thorough investigation of properties of the machine model of the problem, and automatic synthesis of program with taking into account the architecture and structure of the computer as well as at the expense of taking into account characteristical features of compilers, etc.

The realization times for algorithms which take into account problem's properties can be significantly different from the same times for algorithms not taking into account these properties (see fig. 5) [12] .

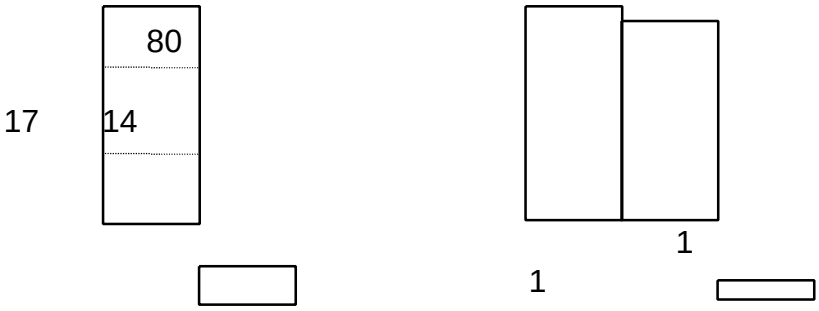


Fig 5.

Fig.6

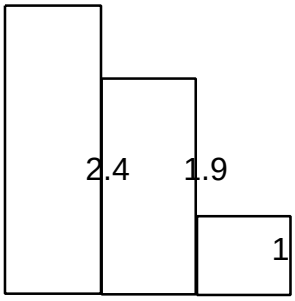
Dependencies of times of realization by computational schemes which take into account characteristical features of archiecture of HP RISC on those not taking into account these characteristical features are depicted on fig.6, which illustrates the reduction

of the problem's solving time at the expense of algorithm's accordance with the computer's architecture [12] .

Advantages of using programs which take into account characteristical features of compilers for different programming languages are depicted on fig.7.

It should be noted that at the expense of using the new architectures of HP RISC microprocessor instead of Motorolla 68040 it became possible to reduce by 5 times the problem's solving time for the programming language C and by 3 times for FORTRAN.

Thus, an intelligent computer will always possess a peak exploitational performance in the process of solving scientific and technical problems due to the fact that such computer will use all the capabilities of ist technical and mathematical means.



occam Fortran îccam/Fortran
Traditional Adapted
programming programming

Fig.7

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