

# NUMERICAL ENGINEERING SOFTWARE

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## **Abstract**

*The Numerical Engineering Software represents an integrated solution for the implementation of a various number of numerical methods in order to obtain viable results to technical problems as fast as possible. The software focuses on the following topics: Matrix Algebra, Interpolation and Polynomial Approximation, Locating Roots of Equations, Numerical Integration and Initial Value Problems for Ordinary Differential Equations. The key features of this project are: the adjustable accuracy of computation, algorithms selection on computational cost criteria and ease of use (no programming abilities required).*

**Key-words:** *linear systems, eigenvalues and eigenvectors, interpolation, numerical integration, Cauchy problems.*

**AMS classification:** 65D05; 65D30; 65F05; 65F10; 65F15; 65L05; 65-04

**CR categories:** D.2.2

## **1. Introduction**

Since the introduction of the computers, numerical analysis has developed into an increasingly important connecting link between pure mathematics and its application in science and technology. The spectacular increasing in computational speed and capacity of the modern computers (the first one doubles around each 18 months, the latter presently reaching 500 Gigaflops), along with the development of the routines libraries, allowed more and more complex problems to be studied not only in devoted research laboratories but also in more common engineering offices. But this improvement did not come without a cost: a wider requirement for basic knowledge in numerical methods and their limitations as well as medium programming skills (which is not in hand to anyone at anytime). This is where our project comes to help. The present paper offers the general characteristics and principles that have governed the development of the Numerical Engineering Software v1.0 project. In the following sections the authors will provide insights on the methods used in the program, the selection criteria and the elements that define our project with special emphasis on the interface of the program which we consider to be one of the most accessible on the market.

## **2. General remarks**

Numerical Engineering Software represents an integrated solution for the implementation of a various range of numerical methods with the purpose of obtaining real-time viable results to basic technical and engineering problems.

The advantages of the program are represented mainly by the user-friendly interface and by the fact that its usage requires no prior programming knowledge, but the restrictions of the problem you are trying to solve. These strong features make the Numerical Engineering Software adaptable for use in a various range of working environments.

The team of developers has long been acquainted with the idea of user-friendly numerical analysis software, producing early on, a similar but less complex solution. That project has since evolved in terms of methods, interface and general quality to the project presented here today – NUMERICAL ENGINEERING SOFTWARE.

The Numerical Engineering Software methods are strictly selected according to computational cost and compatibility criteria. Also, the program includes strong iterative numerical methods adaptable to large scale problems and offering accurate results; this characteristic is strengthened by the adjustable precision of calculus implemented in all the chapters of the application. The user is allowed to choose from several numerical methods the one he considers the most appropriate.

To come to the aid of its users the program also includes a text editor, a simplified organizational structure and various recommendations in order to select the optimum method of calculation and to provide the specific parameters characteristic to each method.

On the market, in the field of solving technical problems through numerical analysis, we can detect a significant number of products from integrated applications for numerical analysis and algebra, to programming languages which extend their area of expertise only to the field of numerical analysis to headers.

The most famous software product with applications, among others, in the field of numerical analysis is Matlab from Math Works company, its current version being the R2008a. However, the complexity of a programming environment such as Matlab may often prove itself extremely difficult for those with limited knowledge of programming.

Our project proposes itself not to imitate Matlab in any way, but only to offer the possibility of solving technical problems to a larger number of users. We consider the presence of Numerical Engineering Software on the market as an imperative of the regional scientific community.

The research and development team of the program wishes to continue developing Numerical Engineering Software in accordance with the specifications stated above.

### **3. List of numerical methods included**

#### *3.1. Matrix algebra*

The solving of linear algebraic systems and matrix calculus operations are included in the field of linear algebra involved in various scientific problems:

- problems depending on a finite number of freedom degrees, represented through ordinary differential equations or through equations with partial derivatives are transformed with the help of finite differences into linear systems;
- nonlinear problems are often solved (approximated) through linearization processes.
- a great range of engineering problems from the fields of electrical wiring, structure analysis, building projects, ships, planes, the transport of liquids and gases through pipes, all rely on a linear system for solving.

The methods included in the first chapter are:

- Gauss elimination method of inverting a matrix
- iterative method of inverting a matrix
- iterative Seidel-Gauss method for large linear systems
- iterative Seidel-Gauss method for sparse matrix linear systems
- LR factorization for solving a linear system
- LR factorization for tridiagonal matrix systems
- LR factorization for pentadiagonal matrix systems
- Fadeev method for determining the *characteristic polynomial*
- Danilevski method for obtaining eigenvalues and eigenvectors

### 3.2. *Interpolation and polynomial approximation*

The need for function approximations arises in many branches of applied mathematics, and computer science in particular. In general, a function approximation problem asks us to select a function among a well-defined class that closely matches ("approximates") a target function in a task-specific way.

To some extent the different problems (regression, classification) have received a unified treatment in statistical learning theory, where they are viewed as supervised learning problems.

The methods included in this chapter: *Lagrange interpolating polynomial*, and *Discrete least square approximation*.

### 3.3. *Locating roots of equations*

The method included in this chapter is the famous and reliable Bairstow's method for the calculus of the roots (real or complex) of an algebraic equation.

### 3.4. *Numerical integration*

The methods included in this chapter are: Newton integration method for evaluating simple integrals, and a method for evaluating double integrals with convex boundary domains.

### 3.5. *Initial value problems for ordinary differential equations*

Ordinary or partially derived differential equations represent mathematical models for the majority of engineering problems: the study of efforts to which resistance elements are exposed: bars, pillars, thin plates, thick plates, pipes; the study of electrical fields in dielectrics problems, magnetic and thermal fields, the propagation of all types of waves and the list goes on.

Once the physical phenomenon and the differential equations that govern it, boundary conditions and coefficients are stated, only one issue remains: the solving of this mathematical model. For various reasons: physical differences, boundaries with an unusual geometry etc., the solving of this mathematical model will consist of the search for an approximate solution using the computer – the numerical computation.

The methods included in this chapter are: Euler method for the solving of a Cauchy I-st order problem, and a 4-th order Runge-Kutta method for solving Cauchy I-st order problems.

## 4. **General presentation of the interface**

This section is dedicated to presenting the main features of the Numerical Engineering Software interface. The program was built around an interface in

Romanian and it is already running in the laboratories of our faculty. That is why the prints below are in Romanian, but the English language option for the interface of the program is also available.

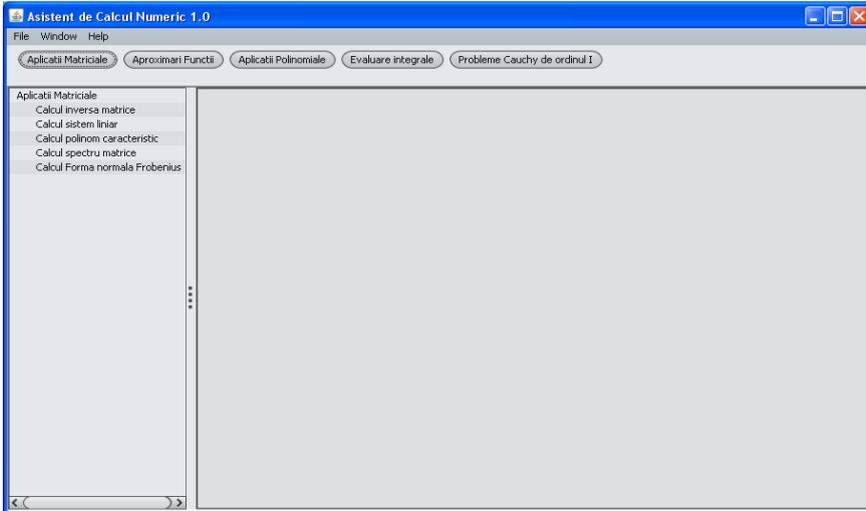


Figure 1. *The basic interface of Numerical Engineering Software*

Figure 1 represents the basic interface of Numerical Engineering Software. In other words, this is the main window of the program which appears after the program is loaded and the introductory window is closed.

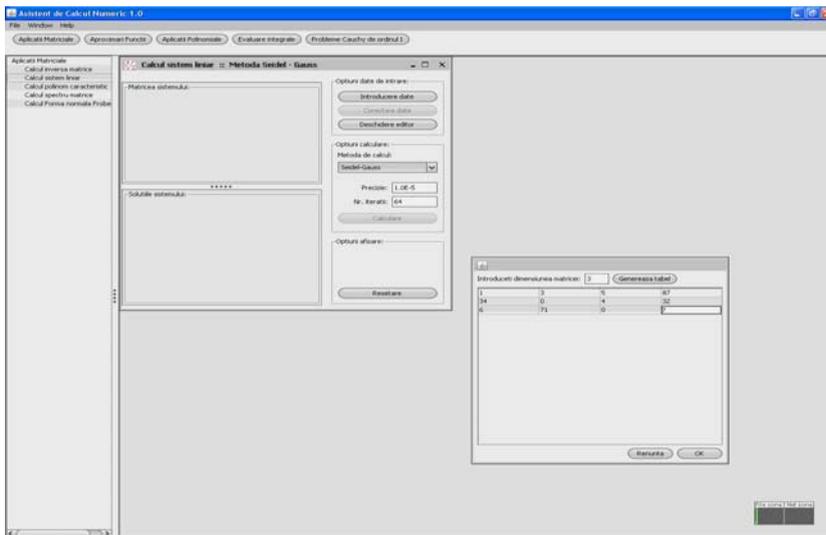


Figure 2. *Example of a menu for computing a linear system (Matrix Algebra)*

Figure 2 presents the data window for the calculus of a linear system with the default settings Seidel-Gauss iterative method,  $1.0E-5$  precision and maximum number of iterations of 64.

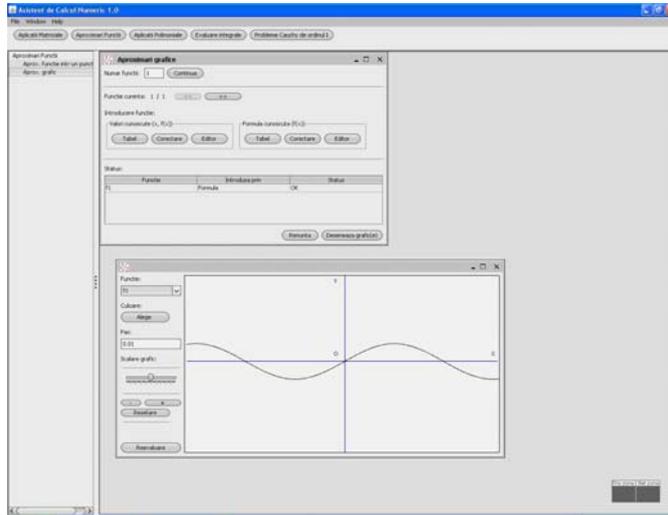


Figure 3. The data window for graphic approximation of functions (Interpolation and Polynomial Approximations)

The user has the possibility to choose the interpolating polynomial degree; furthermore he can zoom in the graphic window for more details and change the colour for a better contrast.

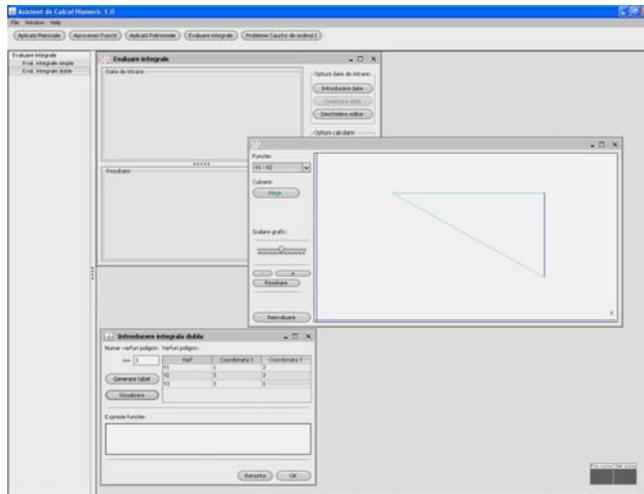


Figure 4. The data window for evaluating a double integral (Numerical Integration)

The graphic window presents the integration domain. The same zoom in and colour options are also available.

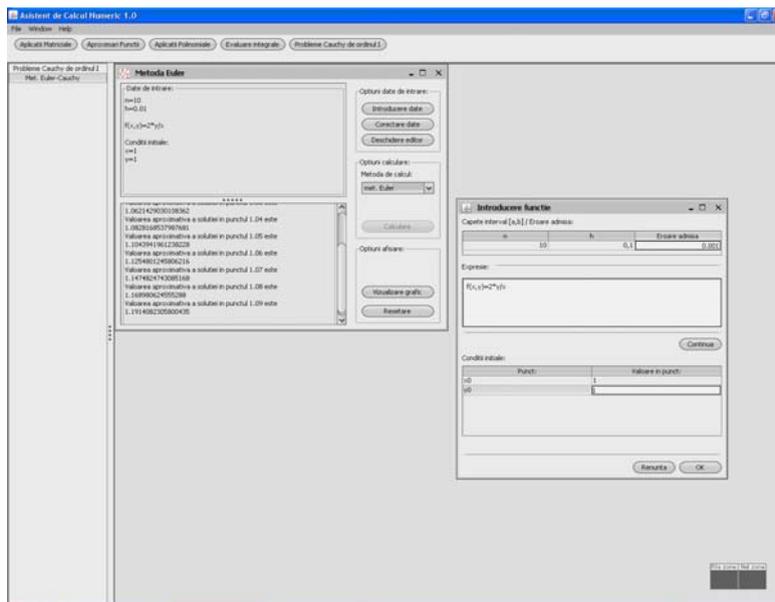


Figure 5. The data window for calculating a Cauchy I-st order problem

The accuracy of computation may be imposed by the user for both Euler and Runge-Kutta methods.

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