



THE MATH – OPEN SOURCE APPLICATION FOR EASIER LEARNING OF NUMERICAL MATHEMATICS

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Abstract: The article introduces a software application (MATH) supporting an education of Applied Mathematics, with focus on Numerical Mathematics. The MATH is an easy to use tool supporting various numerical methods calculations with graphical user interface and integrated plotting tool for graphical representation written in Qt with extensive use of Qwt library and other 3rd party libraries. The MATH is a convenient tool for use in education process, thanks to its capability of showing step-by-step solutions for better understanding of the whole process for both undergraduate and graduate students. It enables also speed and precision comparison for various similar methods. The main goal of this application was to support student learning process and after all, speed up the learning curve.

Key words: Numerical Methods, Step-by-Step Solutions, Qt, LMS Approximation, Error Estimation

1. Introduction

Numerical analysis is a subject of extreme interest to mathematicians, computer scientists and engineers who could profit from the mentioned application. In the process of learning the mathematics and especially in the case of undergraduates, understanding the basics of numerical mathematics plays the key role. In order to be able to choose the best suited numerical method, one has to be aware of how those various numerical methods work, their advantages and disadvantages in a form of a calculation speed, precision and complexity.

There are several open source and web-based application with similar capabilities (that the author are aware of), but they are usually not designed for understanding the very basics of various numerical methods, which are very important and so not very well suited for education process.

2. Motivation

For engineers and scientists, there is often a question which method will work the best, is the most accurate, the fastest, etc. To be able to correctly decide, there is important to know the basis and the core of all those methods that are available to use. As the application is designed mainly for educational purposes, to achieve this goal, the application was designed to show not only results, but also partial results and solutions. This step-by-step approach is important for understanding how these methods work and realize all important steps. The MATH connects the ability to solve numerical problems and visualize it with a few simple steps.

To summarize, the MATH application is designed to achieve several goals:

- Provide all calculation steps for each numerical method with easy to use graphical interface.
- Enable graphical visualization of calculated data as well as the option of exporting acquired data and graphs in suitable formats.

3. The Software architecture and design

The MATH application covers all methods needed by students for their further specialized studies. It provides so far these numerical methods for calculation and comparison [9] [10] [11] [12] [13]:

- 1) Nonlinear equation
 - Bisection method
 - Regula Falsi method
 - Secant method
 - Newton method
 - Iteration method
- 2) Definite integration
 - Rectangular method
 - Trapezoid method
 - Simpson's method
 - Monte Carlo Hit of Miss method
 - Monte Carlo Average method
- 3) Double definite integration (Monte Carlo method)
- 4) Numerical differentiation (up to 4. degree of differentiation)
- 5) System of linear equations
 - Jacobi Iteration method
- 6) Matrix calculation (basic numerical operations, transpose, inverse, etc.)
- 7) The least mean square approximation (LMS)

The MATH application can be extended by additional Numerical methods since it is open source. The MATH is used as an education tool on several faculties of Technical University of Kosice. There are still many numerical methods and graphical capabilities to be implemented in the close future.

The MATH is designed in the Qt 4.8.1 [1], which is a C++ graphical framework for cross-platform application development. We have used two more 3rd party libraries MuParser [2] and Gsl [3] for parsing the expressions and matrix calculation. For plotting is used Qwt library [4]. The graphical user interface (GUI), shown on Figure 1 provides users the options for choosing from presented numerical methods, graphical visualization, and data export. Data and graphs can be exported in the most common formats (PDF, PNG, JPEG, TXT, etc.)

Before publishing, a trial run with students from Technical University of Kosice was performed, using input data (problem to solve) from lectures of Applied Mathematics in order to test its usability and detect any bugs. All final results were compared and checked against the results from Matlab [8] to ensure the desired precision of all used methods, as Matlab includes many, more advanced methods with higher precision. With Matlab we performed test of all methods available in MATH, also for limit values that could cause problems based on the principle of individual algorithms. These tests verify that all methods work correctly with desired precision. Although, various limit cases were tested, there still may occur some bugs considering special cases. For such occasion, there is support available through e-mail or MATH website. The MATH can be downloaded from MATH website [6] or from MATH source code repository [5].

As you can see on the Figure 1, in the lower part is a list of all built-in functions that can be used in function prescriptions with their brief description. The MATH supports also graphical output, to

visualize used functions and results of numerical method calculations. Graph dialog window is shown on Figure 2. All information about the MATH and how to use it can be found at [5].

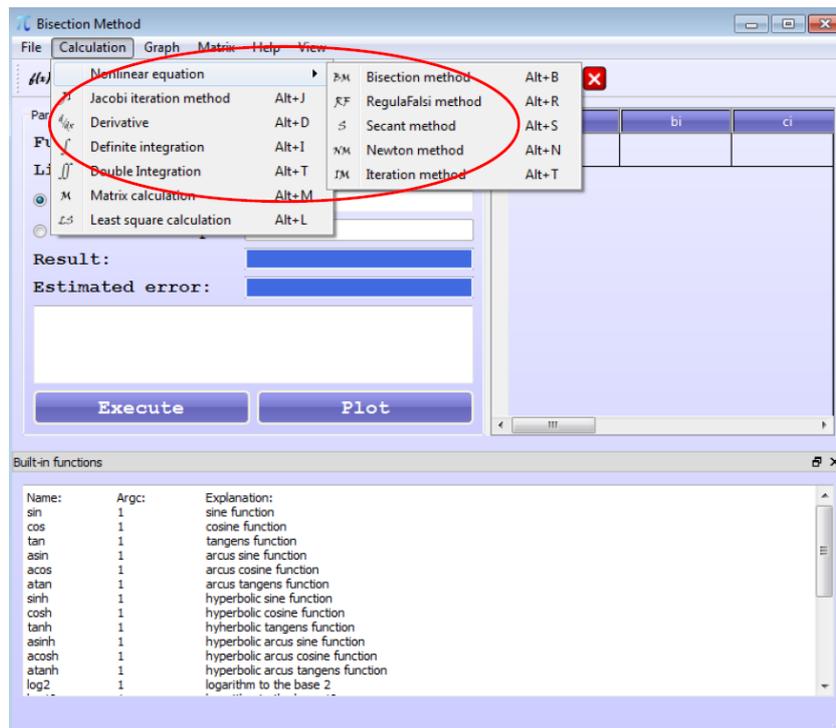


Figure 1. The MATH GUI and its main components.

Main GUI window can have various forms. Each form depends on the chosen method used for calculation, but is displayed in the same main window.

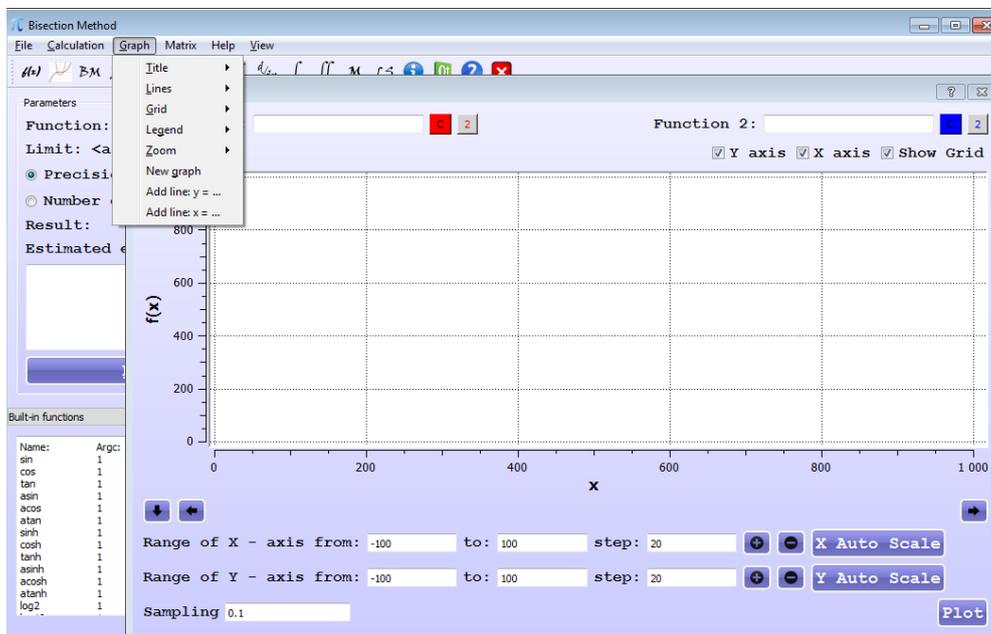


Figure 2. The MATH Graph Dialog Window.

There are many properties that can be modified directly from GUI as shown above on Figure 2. Adjusting the graph dialog window is very intuitive as well as using the main GUI for numerical calculation. This plotting tool has the most of commonly used options like changing lines color, width, zooming, adjusting grids, axis, title, labels, etc.

4. Numerical mathematics problem example

Numerical mathematics and MATH specifically, can be used in various situations. For example to use derivative to determine the change of the system with time, figure out the character of that change, calculating the velocity of object using linear equation, or make a prediction using LMS algorithm. The MATH offers several options to choose from and compare the results using more than one method.

For an example we have chosen the numerical integration, due to its high potential and importance in many sectors of engineering and science. Consider that we need to determine the value of simple integral as shown below on Figure 3.

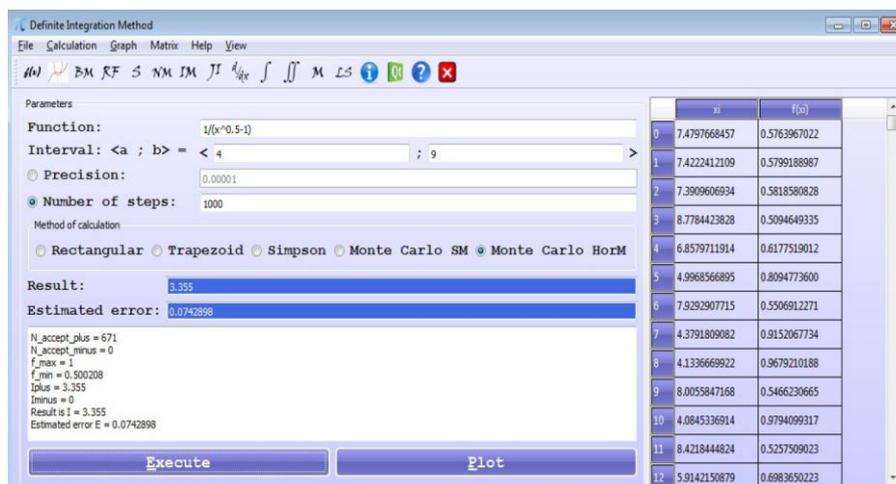


Figure 3. Definite integration using Monte Carlo Hit or Miss method.

Using this simple GUI we can get the result with all partial results in a very short time. As you can see on Figure 3, we have chosen to specify the number of steps, but we can do the same for defined precision and then compare the results with other method with just a few clicks, without the need of time consuming calculation. The results from this calculation can be visualized as seen on Figure 4.

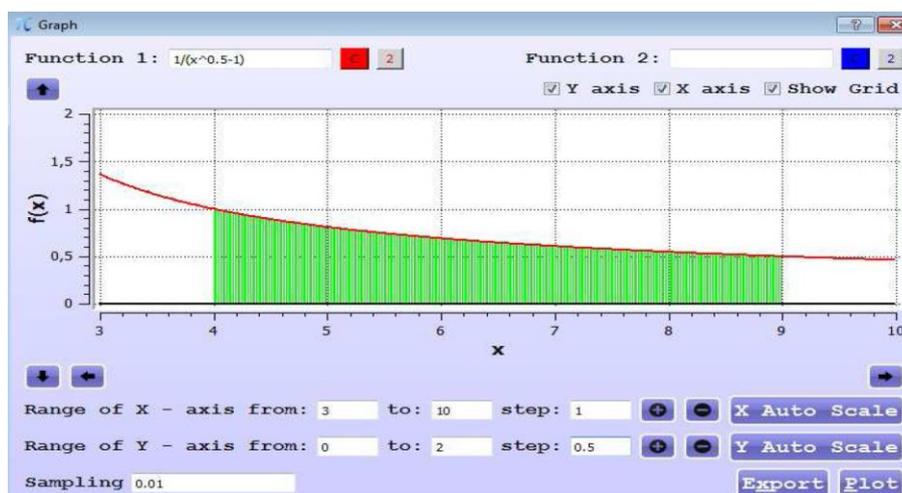


Figure 4. Graphical visualization of definite integration using Monte Carlo Hit or Miss method.

Of course, one can use already developed, well documented and robust libraries for scientific applications like SciPy, Maxima, Octave, Matlab, and many others, but those libraries and applications offer only final results and graphical visualization. For students however, it is more convenient to see the whole process and the possibility of partial results verifications and comparison with other methods, than just to see the results.

More detailed implementation of each separate method and how to use it can be found in MATH documentation at [5].

5. The MATH in education process

We use the MATH application while teaching Numerical methods during the course named Applied Mathematics in Sensorics and Avionics System program at the Technical University of Košice. During the lectures of numerical methods we focus on methods which are necessary for further studying of vocational subjects. We use a calculator as primary tool to solve simple problems. This hand calculation is important because it helps students to better understand each methods. Finally we use MATH in practice of Applied Mathematics course for controlling hand calculation problems. Because MATH is available for free, students can use it at home to check their hand calculation. They can compare the calculations to find a mistake if any.

Another great advantage of MATH is that it is an open source, meaning that anybody can contribute and broaden the options and list of all numerical methods. In this way, students that are more advance, as this happens in every class, can program new methods right into MATH. This kind of contribution requires along with some programming skills, deeper understanding of that particular method and considering all limit situations that can be experienced.

To help the students with learning on how to use the application, there has been published a publication with examples from numerical mathematics using MATH as a tool [7].

6. Conclusion

The MATH as an application provides easy to use tool for calculating roots of nonlinear equations, roots of system of linear equations, differentiate, integrate, approximation, matrix calculation using mentioned numerical methods, to calculate results, estimate errors and much more. The MATH is completed with graphical visualization capable of producing publication quality figures. Future development will be aimed on expanding the numerical methods and graphical capabilities. The MATH has already been implemented into the education process at Technical University of Košice. The MATH's reuse potential lies in every university, where undergraduate or graduate students need to understand numerical mathematics on a fundamental level. Engineers, computer scientists and others, often needs to know which method will be most efficient or most precise, and the MATH is capable of providing such information. The MATH also supports different method performance comparison and graphical visualization, which can be used as a separate tool providing plotting options just as any other plotting tool that can be extended depending on future requirements.

Implementation of the MATH into the education process, revealed a great potential in helping undergraduate and graduate students with numerical mathematics and improving their skills faster than with conventional methods in lecturing.

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