Current Trends in Computer Sciences & Applications

DOI: 10.32474/CTCSA.2025.03.000168

ISSN: 2643-6744

Review Article

Possibilities of Using Symbolic Computation in Technical Applications

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Received: August 01, 2025 **Published:** August 05, 2025

Abstract

Symbolic computations involve the manipulation of mathematical expressions in their general algebraic form, enabling the results to be expressed as symbolic functions. Computer algebra, a relatively recent term, refers to software programs that facilitate calculations on symbols, thereby extending computational capabilities beyond numerical operations towards algebraic transformations, mathematical logic, and formal descriptions. Analysis of the results indicates that symbolic computation systems, are useful for addressing issues related to the dynamics of systems. In addition to providing symbolic results that can be variously edited, they also offer comprehensive tools for visualizing the obtained results. Using Computer Algebra Systems (CAS), one can, in many cases, attain analytical solutions even for problems where traditional methods are prohibitively time-consuming or, at times, impossible.

Introduction

Symbolic calculations and numerical calculations are two different approaches to mathematical analysis. Symbolic calculations are based on the manipulation of mathematical expressions in their general, algebraic form, which allows results in the form of symbolic functions. Numerical calculations, on the other hand, are based on operations performed on specific numbers, which leads to results in the form of approximate numerical values, often representing points showing the variability of a given function. Both approaches have their applications depending on the type of problem and the required precision or generality of the solution. Symbolic computation systems may be useful in solving problems related to the dynamics of systems. They offer the possibility of obtaining symbolic results that can be edited and visualized with the use of extensive tools. Thanks to CAS packages, it is possible to obtain analytical solutions even for very complex cases, which would be time-consuming or impossible to solve with traditional methods.

Algebra is one of the oldest branches of mathematics created in antiquity, which has undergone many transformations over the years, developing and covering new areas of knowledge. The origin of the name indicates that initially, algebra dealt with solving equations of the first and second degree with numerical coefficients. Computer algebra is a relatively young term, denoting computer programs that allow calculations to be performed on symbols. This allows calculations to be made with the use of a computer that go beyond the world of numbers, towards algebraic transformations, mathematical logic, or even formal descriptions.

CAS systems, *short for Computer Algebra System*, are specialized computer software that supports symbolic calculations in mathematics, physics and technical disciplines [1]. Computational algebra systems basically began to appear in the early 1970s, as a side effect of the research on artificial intelligence already carried out at that time. The pioneer of CAS systems was the Nobel Prize winner Martinus J. G. Veltman, who in 1963 developed the Schoonschip program [2], designed to be used especially to solve problems in high energy physics. It originally ran on a mainframe IBM 7094.

In parallel with the development of large computer systems, specialized calculators offering the possibility of symbolic calculations were developed. For example, in 1987, HP introduced its first CAS calculator, which was the first portable device to enable symbolic calculations [3]. In 1995, Texas instruments introduced the Ti-92 calculator with advanced CAS support, based on the Derive package. The TI-xx line of calculators continues to this day, and the latest model is the TI NSPIRE CX II-T CAS.

CAS systems in dynamic issues

The first widely known and popular CAS systems were muMATH, Reduce, Derive and Macsyma. They initiated the development of this technology [4], offering, among others, tools for solving equations, differentiation, integration and many other algebraic operations. Their emergence has significantly influenced the way scientific research and mathematics education is conducted, becoming an indispensable support for scholars, students and engineers. These systems were the foundation for later, more advanced solutions, which today are an integral part of many fields of science and technology. An important position in today's CAS market today is Mathematica [5], which is the system most commonly used by mathematicians, scientists, and engineers. One of the most well-known programs for solving problems using symbolic methods is the Maple package [6]. From the point of view of applications in the analysis of problems in the field of technical issues, especially those related to the analysis of dynamics, it is important that it implements the most advanced among all CAS systems "solvers" for the symbolic solution of ordinary and partial differential equations.

Since symbolic calculations are operations performed on mathematical expressions, in the case of solving differential equations, the result of such calculations is always a function in symbolic form. Numerical calculations are calculations on numbers, their result is always points that are an approximation of the course of variability of this function. This allows to avoid a number of problems related to the use of algorithms and packages using them to numerically solve systems of differential equations, such as numerical errors. In addition, it is worth noting that obtaining a specific, numerical solution comes down to relatively simple algebraic calculations and is much faster than obtaining a solution by numerical integration of differential equations. This can be important, for example, when model-based control systems are implemented in practice using embedded systems with low computing power.

Consider, for example, the case of a simple mechanical oscillating system with one degree of freedom with a sinusoidally variable force excitation, as shown in Figure 1.

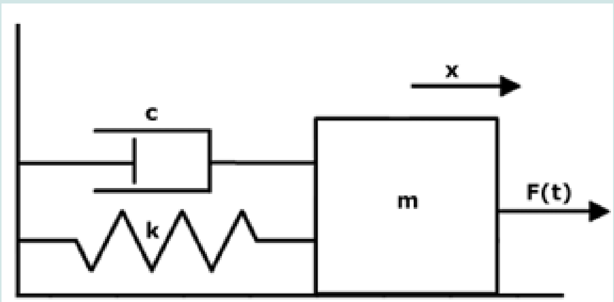

Figure 1: The analyzed system with one degree of freedom.

Let us assume the general character of the forcing force in the form of:

$$F(t) = F_0 \sin(\omega t) \quad (1)$$

Thus, the dynamic equation of motion has the form:

$$m\ddot{x} + \dot{c}x + kx = F(t) \quad (2)$$

For a person using analytical methods, the solution, i.e. finding the general integral for this relatively simple problem, is not at all very simple and fast, unlike the solution using the CAS system is not problematic, as shown in Figure 2 below:

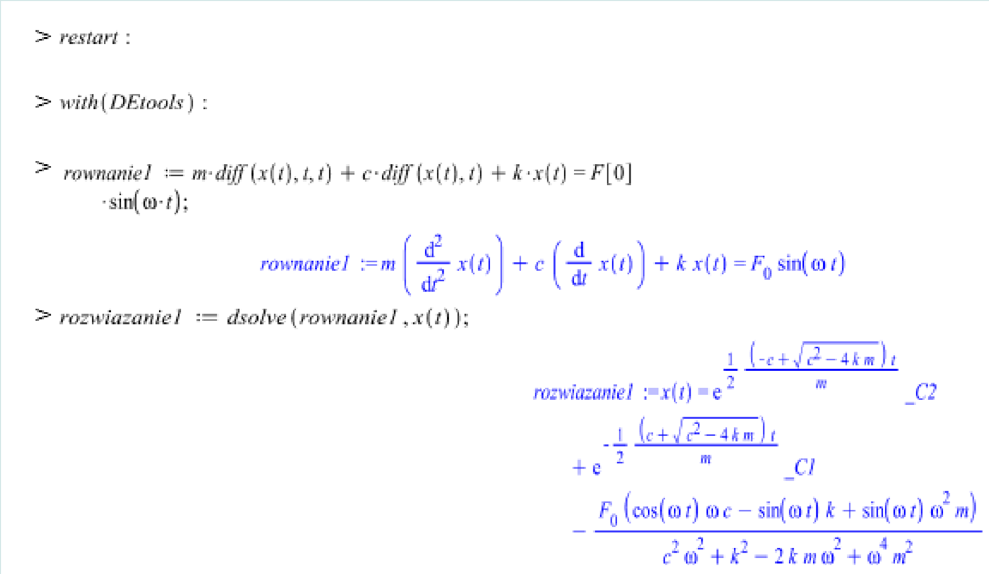

Figure 2: The solution obtained in the Maple system on the computer screen.

Searching for the general integral of an equation and analyzing its solution using the Maple package:

Analyzing the results obtained, it can be concluded that symbolic calculation systems on the example of the Maple package can be useful for solving problems related to the dynamics of systems. In addition to the symbolic results, which can then be edited in various ways, they also provide extensive tools with which to visualize the results obtained. With the help of CAS packages, in many cases, it is possible to obtain analytical solutions even for cases in which obtaining it using traditional methods is extremely time-consuming, and sometimes even impossible.

Conclusions

Symbolic calculation systems such can be an extremely useful tool in the analysis of issues related to the dynamics of systems. With symbolic results that can be freely edited and customized, you have the flexibility to work on a variety of problems. In addition, packages of this type offer advanced data visualization tools, which allows for a better understanding and interpretation of the results obtained. In many cases, CAS systems can provide analytical solutions to problems that would be extremely difficult or sometimes impossible to solve using traditional methods. As a result, they provide irreplaceable support in scientific and engineering work, accelerating computational processes and opening up new research opportunities. It is also worth noting that the rapid achievement of a numerical solution through simple algebraic calculations can be important in practical applications, especially in the case of control systems implemented on microcontrollers with limited computing power.

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