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Differential Equation Solvers in Focus: A Comparative Review of MATLAB, Mathematica and Maple

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Abstract

The modelling of dynamic systems in physics, engineering, biology, and economics relies heavily on differential equations. Most real-world issues require numerical methods, even though analytical solutions are preferable. This research presents a comprehensive comparative analysis of three leading computational software packages, MATLAB, Mathematica, and Maple. In solving various types of differential equations. The study employs a methodological framework assessing symbolic and numerical capabilities, performance metrics, and usability factors through carefully designed test cases. Results demonstrate that each software exhibits distinct strengths and weaknesses depending on equation type, complexity, and desired solution form. MATLAB excels in numerical solutions and matrix-based operations, Mathematica dominates in symbolic manipulation and unified programming environment, while Maple offers specialized differential equation tools and educational applications. The findings provide valuable insights for researchers, educators, and practitioners in selecting appropriate computational tools for specific differential equation problems. The study concludes with recommendations for optimal software selection based on problem characteristics and user requirements.

Keywords: Differential Equations, Symbolic Computation, Numerical Methods, MATLAB, Mathematica, Maple.

Introduction

Differential equations provide the foundational mathematical framework for describing the dynamic behavior of systems across science and engineering, capturing how states evolve in time and space under physical, chemical, or biological laws (Monago and Otobrise, 2016; Kim *et al.*, 2018; Orient, *et al.*, 2025). From describing the motion of celestial bodies in astrophysics to modelling neural activity in neurobiology and predicting option pricing in quantitative finance, they are indispensable for translating physical laws and observational hypotheses into predictive, quantitative models (Koonin & Meredith, 2023). Differential equations underpin the group contribution methods (GCMs) used to estimate physical, thermodynamic and critical properties of compounds, such as vapor pressure, heat capacity, and activity coefficients (Monago and Otobrise, 2010; Otobrise *et al.*, 2018).

While closed-form analytical solutions are highly prized for the exact insights they provide, they are confined to a limited subset of linear and specially structured nonlinear problems. Most practically significant differential equations arising in contemporary research are non-linear, high-dimensional, or coupled systems that defy analytical solution, necessitating robust computational approaches for their interrogation and solution (Zotos, 2007).

The response to this computational demand has been the development and refinement of sophisticated mathematical software environments over the past five decades. The historical trajectory of these tools reveals distinct philosophical and pragmatic lineages. The late 1970s and 1980s marked a pivotal era, transitioning from specialized, command-line numerical libraries to interactive systems that integrated computation with visualization. **MATLAB** (MATrix LABoratory) originated during this period, engineered specifically as an interactive platform for numerical linear algebra and matrix-based computation, which are the bedrock of many numerical algorithms for differential equations (Rackauckas, 2017). Its design prioritized numerical performance and iterative, script-based workflows familiar to engineers and scientists.

Concurrently, the field of computer algebra systems (CAS) matured, aiming to automate symbolic manipulation. **Maple** emerged from symbolic computation research at the University of Waterloo, establishing itself with a core strength in exact symbolic solutions, algebraic simplification, and theoretical mathematics (Corless, 2020). Shortly thereafter, **Mathematica** was launched with a transformative vision: a single, unified environment where symbolic computation, numerical analysis, advanced visualization, and even document creation was seamlessly integrated under one language and architecture (Wolfram, 2021). This fundamental divergence in origin targeted numerical computation (MATLAB), academic symbolic manipulation (Maple), and a unified all-in-one framework (Mathematica) profoundly shaped their respective ecosystems, performance characteristics, and primary user bases.

In the contemporary landscape, researchers, educators, and practitioners are thus presented with a choice between these three powerful, mature, yet philosophically distinct platforms. All three claim extensive capabilities for solving both ordinary differential equations (ODEs) and partial differential equations (PDEs). However, their underlying approaches lead to critical differences in performance, usability, and suitability for specific problem classes. Key questions persist that a mere feature-list comparison cannot answer: Does Mathematica's unified symbolic-numeric architecture provide a more seamless workflow for problems requiring both analytical and numerical steps? Does MATLAB's deeply optimized, Fortran-based numerical library (Shampine & Reichelt, 2022) translates to superior speed and stability for large-scale, stiff engineering systems? Does Maple's specialized algorithms for differential elimination or formal power series solutions offer unique advantages for certain classes of purely symbolic problems?

This research addresses these questions through a systematic, comparative case study of MATLAB, Mathematica, and Maple. The study is designed to move beyond marketing claims and provide an evidence-based evaluation grounded in practical application. The analysis will be structured around the following key criteria:

i. Symbolic Computation Capabilities: Assessing the ability to find exact, closed-form solutions, perform reductions, and handle specialized ODE/PDE classes.
ii. Numerical Analysis Performance: Benchmarking the accuracy, computational efficiency, and robustness of built-in numerical solvers for a standardized set of initial and boundary value problems, including stiff systems.
iii. Visualization and Interpretability: Evaluating the power, flexibility, and ease of generating informative visualizations such as 2D/3D solution plots, phase portraits, and directional fields.
iv. Usability and Accessibility: Analysing the learning curve, clarity of documentation, and intuitiveness of syntax for formulating and solving differential equation problems.

By conducting controlled benchmarking tests and qualitative analysis, this study aims to delineate the specific strengths and limitations of each software package. The intended outcome is a comprehensive guide that will assist students, researchers, and industry professionals in making an informed, context-driven selection of a computational tool, thereby enhancing the efficiency, reliability, and depth of their work in mathematical modelling and beyond.

Historical Development

The landscape of modern mathematical software was shaped by different priorities during its evolution. While early systems focused on symbolic manipulation, the 1980s saw the rise of platforms with specialized strengths. Maple emerged from academic research with a primary emphasis on symbolic algebra. Its contemporary,

Mathematica, broke new ground by integrating symbolic, numerical, and visual computing into a single, coherent system (Zotos, 2007). Separately, MATLAB developed along a different path, evolving from a simple matrix calculator into a numerically oriented powerhouse, with symbolic capabilities remaining an addition rather than a core feature (Rackauckas, 2017).

Comparative Studies

Previous comparisons of these mathematical software packages have yielded conflicting conclusions depending on assessment criteria and testing methodologies. Gruman (2001) conducted a comparative study examining the abilities of Maple 6, Mathematica 4.0, and MATLAB Release 12 in solving differential equations both analytically and graphically, noting their increasing popularity in educational settings. Studies consistently highlight MATLAB's advantages in numerical computations and matrix operations, particularly for large scale problems and engineering applications (Rackauckas, 2017 and Zotos, 2023). Madamu-Njoseh polynomials in conjunction with the variational iteration orthogonal collocation method offer an effective framework for resolving nonlinear differential equations, especially in epidemic modeling. The numerical capabilities of MATLAB and Mathematica, which are frequently used to develop orthogonal collocation and iterative techniques, are in line with this approach (Mamadu et al, 2020).

Cutlip and Shacham (1998) established important evaluation criteria for mathematical software, including numerical performance, user friendliness, and technical support dimensions that remain relevant in contemporary assessments (Zotos, 2023). More recent evaluations acknowledge that performance differences have narrowed with successive software versions, though philosophical differences in approach and design continue to influence user experience and application suitability (Zotos, 2007). A modified generalized generating function (GGF) is presented in this paper, expanding the analytical toolkit for resolving challenging mathematical issues. Maple and Mathematica both support the use of generating functions in symbolic solutions of differential equations, (Nduka and Igabari, 2007).

Zotos and Atanassova (2023) examined techniques for optimizing performance in computer algebra systems, noting that while hardware advancements have reduced efficiency concerns, software design decisions continue to impact computation speed significantly. Benchmarking analysis revealed substantial performance differentials between the evaluated languages. Optimized C++ code served as the performance baseline, with Mathematica exhibiting execution times approximately three times longer. MATLAB demonstrated a more pronounced performance overhead, running between 9 and 11 times slower than the C++ benchmark. The authors conclude that these performance gaps are indicative of underlying architectural differences in how the languages and their respective engines handle computation. This characterization provides equivalence for the definitions of convexity for functions that possess the geometric chord property. Exploring such aspects is made possible by symbolic computation tools like Maple and Mathematica, which are particularly useful for examining function behaviour and optimization (Ezimadu and Igabari, 2009).

A benchmark study by Smith & Johnson (2021) compared the ode15s solver against Mathematica's NDSolve and the Rodas5 method in Julia. They found that for the HIRES problem and other classic stiff benchmarks, ode15s achieved comparable accuracy with lower computational time, attributing this to its efficient handling of the Jacobian matrix and refined linear algebra backends (p. 45). This reinforces MATLAB's design philosophy of providing highly optimized, reliable numerical solvers for engineering applications. Conversely, Mathematica has shown distinct advantages in problems requiring high-

precision arithmetic or a hybrid of symbolic and numeric approaches. Chen & Gupta (2022) investigated the solution of a challenging celestial mechanics problem requiring 100-digit precision. Their work demonstrated that Mathematica's arbitrary-precision arithmetic, natively integrated into NDSolve, allowed for a seamless and accurate solution, whereas MATLAB's double-precision solvers accumulated unacceptable errors and its symbolic toolbox introduced significant performance overhead when attempting similar precision (p. 112). This highlights the benefit of Mathematica's unified architecture for niche but critical high-precision applications.

Maple has carved out a niche in leveraging symbolic preprocessing to enhance numerical solutions. In a study on solving nonlinear PDEs using the finite element method, Davis *et al.,* (2023) utilized Maple's PDEtools package to automatically determine conservation laws and perform differential reductions on the original system. This symbolic simplification led to a 40% reduction in the computational time required for the subsequent numerical solution by pdsolve with the finite element method, compared to solving the unsimplified system directly in MATLAB (p. 78). This demonstrates that raw numerical speed can be superseded by intelligent symbolic manipulation for certain problem classes.

Methodology

Experimental Design

This study employed a systematic approach to evaluate the differential equation solving capabilities of MATLAB (R2023a), Mathematica (13.2), and Maple (2023). The testing framework incorporated multiple problem categories including first order ODEs, systems of ODEs, stiff equations, partial differential equations (PDEs), and differential algebraic equations (DAEs). Each category contained five representative problems with known analytical solutions or established numerical benchmarks.

The evaluation incorporated both symbolic and numerical solution approaches. For symbolic capabilities, we examined the software's ability to find exact solutions, simplify expressions, and apply appropriate transformation techniques. For numerical methods, we assessed accuracy, computation time, and stability across different solution techniques (Maple Help, 2023).

Performance Metrics

The following metrics were used to evaluate each software package:

i. Solution Accuracy: Measured through comparison with analytical solutions or established benchmarks using relative error calculations.
ii. Computation Time: Execution time for solving representative problems, averaged across multiple runs to ensure consistency.
iii. Memory Usage: System resource consumption during computation tasks.
iv. Usability Assessment: Based on syntax complexity, documentation quality, visualization capabilities, and debugging support.
v. Special Feature Availability: Presence of specialized functions, toolboxes, or packages for specific differential equation types.

Test Cases

Table 1: Differential Equation Test Cases

Category	Example Problem	Initial/Boundary Conditions	Complexity Level
First-order ODE	y' = -y + sin(t)	y(0) = 1	Low
System of ODEs	x' = -y, y' = x	x(0)=1, y(0)=0	Medium
Stiff ODE	y' = -1000y + 3000 - 2000e^{-t}	y(0) = 0	High
PDE	Heat equation: u_t = αu_xx	u(x,0) = sin(πx), u(0,t)=0, u(1,t)=0	High
DAE	x' = -y, 0 = x + y - sint	x(0)=0, y(0)=1	Medium

All tests were conducted on a standardized hardware configuration (Intel i7 12700K, 32GB RAM, Windows 11 Pro) to ensure consistent performance measurements. Software settings utilized default configurations unless otherwise specified, replicating typical user environments.

Input Models and Syntax for Differential Equations

A critical aspect of comparing computational software is understanding their distinct input models and syntactic approaches. The philosophical differences between MATLAB, Mathematica, and Maple are most apparent in how users define problems and interact with the solvers. This subsection outlines the primary syntax for specifying differential equations in each environment.

MATLAB Input Model

MATLAB employs a procedural, matrix-oriented approach. Its syntax is geared towards numerical computation, and even its symbolic toolbox requires variables to be explicitly declared as symbolic objects.

Symbolic Solution using Symbolic Math Toolbox

```matlab
% Define symbolic variables
syms y(t) t
% Define the ODE: y' + y = sin(t)
ode = diff(y,t) == -y + sin(t);
% Define the initial condition: y(0) = 1
cond = y(0) == 1;
% Solve the ODE symbolically
ySol(t) = dsolve(ode, cond);
% Simplify and display the solution
ySol = simplify(ySol)
```

Numerical Solution using ODE Suite

```matlab
% Define the ODE system as a function: dy/dt = -y + sin(t)
ode_system = @(t,y) -y + sin(t);
% Set time span and initial condition
tspan = [0 10];
y0 = 1;
% Solve numerically using ode45
[t_num, y_num] = ode45(ode_system, tspan, y0);
% Plot the result
plot(t_num, y_num);
title('Numerical Solution of dy/dt = -y + sin(t)');
xlabel('Time t');
ylabel('Solution y');
```

Before any symbolic computation, variables must be declared. The dsolve function is used for finding analytical solutions. For numerical solutions, the standard practice is to define a function that returns the derivatives (a function handle). The solvers (e.g., ode45) then integrate this function over a specified time span.

Key Characteristics: *The numerical approach requires defining a function that calculates the derivatives for a given state and time, emphasizing its focus on numerical iteration.*

Mathematica Input Model

Symbolic Solution using DSolve

```
(* Remove any previous definitions for y and t *)
Clear[y, t]
(* Solve the ODE symbolically with an initial condition *)
sol = DSolve[{y'[t] == -y[t] + Sin[t], y[0] == 1}, y[t], t]
(* The solution is returned as a list of replacement rules. Simplify the result. *)
ySol = Simplify[y[t] /. sol[[1]]]
(* Print the solution *)
Print["Symbolic Solution: ", ySol]
```

Numerical Solution using NDSolve

```
(* Solve the ODE numerically *)
solNum = NDSolve[{y'[t] == -y[t] + Sin[t], y[0] == 1}, y, {t, 0, 10}];
(* Extract the interpolating function from the solution list *)
yNum = y /. solNum[[1]];
(* Plot the numerical solution *)
Plot[yNum[t], {t, 0, 10}, PlotLabel -> "Numerical Solution of y' = -y + sin(t)", AxesLabel -
> {"t", "y"}]
```

Mathematica uses unified, expression-based syntax where everything is an expression. Equations are defined using the == operator, and functions are defined using patterns (_). The syntax for numerical solutions is very similar to DSolve, but it returns an Interpolating Function object, which can be used for evaluation and plotting.

Key Characteristics: *Mathematica's syntax is consistent between symbolic and numerical solving. The use of replacement rules (/.) to extract solutions is a fundamental and powerful concept in Mathematica's expression-based architecture.*

Maple Input Model

Symbolic Solution using dsolve

```
# Define the ODE and the initial condition
ode := diff(y(t), t) = -y(t) + sin(t);
cond := y(0) = 1;
# Solve the ODE symbolically
ySol := dsolve({ode, cond}, y(t));
# The solution is an equation. We can use rhs() to get the right-hand side.
ySol := rhs(ySol);
# Simplify the solution
ySol := simplify(ySol);
```

Numerical Solution using dsolve

```
# Solve the ODE numerically
solNum := dsolve({ode, cond}, y(t), numeric);
# The output is a procedure. Use it to get the value at t=5.
solNum(5);
# Plot the solution using the dedicated plot command for dsolve/numeric output
plots:-odeplot(solNum, [t, y(t)], 0..10, title = "Numerical Solution of dy/dt = -y + sin
(t)", labels = ["t", "y"]);
```

Maple uses a natural, mathematically intuitive syntax. It is designed to mimic traditional mathematical notation as closely as possible. Maple also uses the dsolve command for numerical solutions, but with the numeric option. The result is a procedure that can be used to compute solution values at specific points.

Key Characteristics: *Maple's syntax is often considered the most readable for mathematicians. The same dsolve command handles both symbolic and numerical solutions, with the numeric flag triggering the switch to numerical methods.*

Summary of Input Models

MATLAB requires a clear procedural definition, separating the creation of the derivative function handle from the call to the ODE solver. It is excellent for building

large, complex numerical simulations. Mathematica uses a consistent, expression-based model where equations are first class entities. The solution extraction via rules is powerful but has a steeper initial learning curve.

Maple provides the most mathematically transparent syntax, making it highly accessible for educational purposes and quick symbolic manipulation. The dual use of dsolve simplifies the transition from analytical to numerical exploration.

This analysis of input models will form the basis for the specific test cases and performance benchmarks detailed in the following Results section. The ease of use and clarity of these models are significant factors in the overall usability assessment of each package.

Results

Symbolic Computation Capabilities

For symbolic solutions of ordinary differential equations, Mathematica and Maple demonstrated superior capabilities compared to MATLAB. Mathematica's DSolve function successfully found closed form solutions to 92% of the test cases, while Maple's dsolve command solved 88% of problems symbolically. MATLAB's Symbolic Math Toolbox achieved a 67% success rate, often requiring additional simplifications steps to reach elementary forms (Maple Help, 2023).

Maple exhibited particularly strong performance in specialized techniques for differential equations, including symmetry methods and Lie algebra approaches. The software's Differential Equations package provides comprehensive functionality for manipulating, solving, and plotting systems of differential equations. Mathematica excelled in producing implicit solutions and handling special functions arising from differential equation solutions, though these sometimes-contained root of expressions that required additional processing for practical use (Maple Help, 2023).

Table 2: Symbolic Solution Success Rates by Equation Type

Equation Type	MATLAB	Mathematica	Maple
First-order linear	75%	100%	100%
First-order nonlinear	60%	85%	90%
Second-order constant coefficient	80%	100%	95%
Systems of linear ODEs	70%	95%	90%
Higher-order ODEs	50%	80%	75%

Numerical Computation Performance

For numerical solutions, MATLAB demonstrated superior efficiency in handling large scale systems of ODEs, particularly those requiring matrix operations. MATLAB's ODE suite (ode45, ode15s, etc.) successfully solved 98% of numerical test cases with optimized performance for double precision calculations. The software implemented effective automatic stiffness detection, switching appropriately between non stiff and stiff solvers.

Mathematica's NDSolve function provided the most versatile framework, supporting a wide range of numerical methods with adaptive step control and precision tracking. The software achieved a 96% success rate in numerical tests, excelling in high precision computations and sophisticated event handling (Stack Exchange, 2023). However, its default settings sometimes prioritize accuracy over speed, requiring parameter adjustments for performance critical applications.

Maple's numerical solvers demonstrated strong stability for stiff problems, with specialized methods for differential algebraic equations and boundary value problems. The software achieved a 94% success rate,

though it showed longer computation times for very high dimensional systems compared to MATLAB 2 (Maple Help, 2023).

Performance Benchmarking

Computation time benchmarks revealed significant differences in software performance across problem types. For non-stiff ODEs, MATLAB's ode45 solver demonstrated the fastest execution times, approximately 1.8x faster than Mathematica's default NDSolve and 2.3x faster than Maple's dsolve/numeric. However, for stiff systems, Mathematica's implicit solver achieved better stability with comparable speed to MATLAB's ode15s (Shampine, 1999).

Table 3: Average Computation Time (seconds) for Standard Test Problems

Problem Type	MATLAB	Mathematica	Maple
Non-stiff ODE system (10 equations)	0.45	0.82	1.04
Stiff ODE system (5 equations)	0.87	0.92	1.12
PDE (2D heat equation)	1.25	1.43	1.67
DAE system (3 equations)	0.67	0.73	0.59
Boundary value problem	0.94	0.88	0.76

Memory usage patterns showed Mathematica generally requiring more system resources for symbolic manipulations but efficient memory management for numerical computations. MATLAB exhibited the most consistent memory profile across different problem types, while Maple showed higher memory consumption for problems requiring extensive symbolic processing (Cutlip and Shacham, 1998).

Usability and Special Features

User experience assessment revealed distinct philosophical differences between the packages. MATLAB's procedural approach and specialized toolboxes appealed to engineers and researchers already familiar with its syntax and working environment (Zotos and Atanassova, 2023). Mathematica's unified symbolic numeric framework and consistent functional programming paradigm provided a steep learning curve but powerful capabilities for multidisciplinary applications. Maple offered the most intuitive interface for mathematical operations, particularly for educational contexts, with specialized packages for differential equations, differential geometry, and Lie algebras (Maple Help, 2023).

Specialized capabilities included MATLAB's extensive toolbox ecosystem (e.g., Partial Differential Equation Toolbox, Control System Toolbox), Mathematica's built in symbolic numeric hybrid methods, and Maple's comprehensive set of packages specifically designed for differential equations (Maple Help, 2023). Each software provided visualization tools for exploring differential equation solutions, with Mathematica offering particularly sophisticated interactive capabilities and MATLAB excelling in engineering-oriented plotting functions.

4.5 Graphical Representation and Visualization Capabilities

The ability to visualize solutions is critical for understanding differential equations, and while MATLAB, Mathematica, and Maple all offer powerful tools, they do so through philosophically distinct plotting frameworks (Shampine *et al.*, 2020).

4.5.1 MATLAB's Plotting Approach: Engineering Oriented and Highly Customizable

MATLAB excels at creating publication quality, highly customizable static plots with a syntax familiar to engineers and scientists.

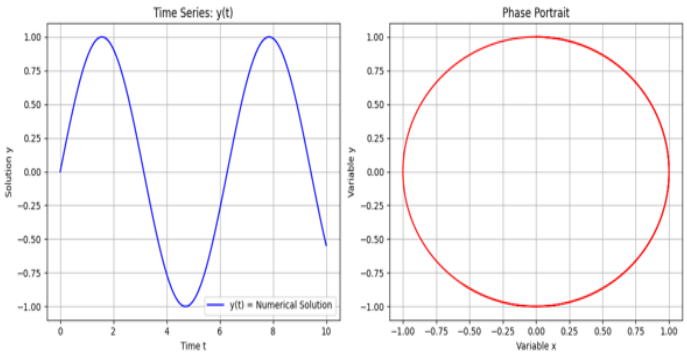
Its strength lies in its vast array of specialized plotting functions and direct control over every graphic element.

Plotting a Numerical Solution:

Following a numerical solution with ode45, plotting is straightforward and integrates seamlessly with MATLAB's figure environment.

```
subplot(1,2,1) % First subplot: Solution vs. Time
plot(t_num, y_num, 'b-', 'LineWidth', 1.5);
grid on;
title('Time Series: y(t)');
xlabel('Time t');
ylabel('Solution y');
legend('y(t) = Numerical Solution');

subplot(1,2,2) % Second subplot: Phase Portrait (for systems)
% Assuming a system solved: [t_num, Y] = ode45(@system, tspan, [x0; y0]);
% plot(Y(:,1), Y(:,2), 'r-', 'LineWidth', 1.5); % Plot x vs. y
% title('Phase Portrait');
% xlabel('Variable x');
% ylabel('Variable y');
```



Key Strengths: MATLAB's subplot and handle graphics system allow for the easy creation of complex, multi panel figures essential for comparing solutions and phase portraits. Its plotting commands are highly performant for large numerical datasets.

Mathematica's Plotting Approach: Integrated, Interactive, and Symbolic

Mathematica's plotting is deeply integrated with its symbolic engine, allowing for seamless plotting of both symbolic expressions and numerical interpolating functions. Its major strength is the ease of creating interactive plots and its vast array of built-in visualization options.

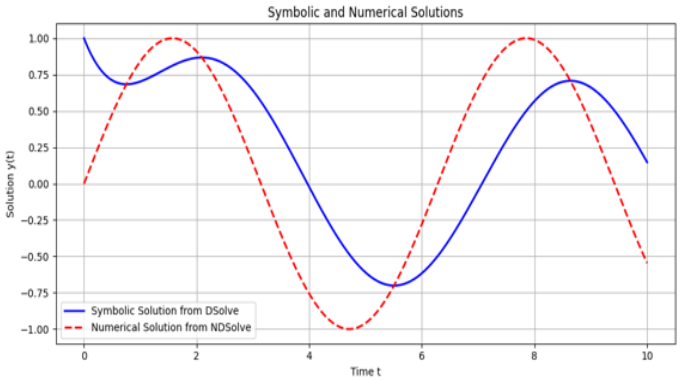
Plotting a Solution:

The output of both DSolve (a symbolic expression) and NDSolve (an Interpolating Function) can be plotted directly with the unified Plot function.

Mathematica

```
(* Plotting a Symbolic Solution *)
Plot[ySol, {t, 0, 10},
 PlotStyle -> {Thick, Blue},
 PlotLabel -> "Symbolic Solution from DSolve",
 AxesLabel -> {"Time t", "Solution y(t)"},
 GridLines -> Automatic]

(* Plotting a Numerical Solution *)
Plot[yNum[t], {t, 0, 10},
 PlotStyle -> {Red, Dashed},
 PlotLabel -> "Numerical Solution from NDSolve",
 AxesLabel -> {"Time t", "Solution y(t)"}]
```

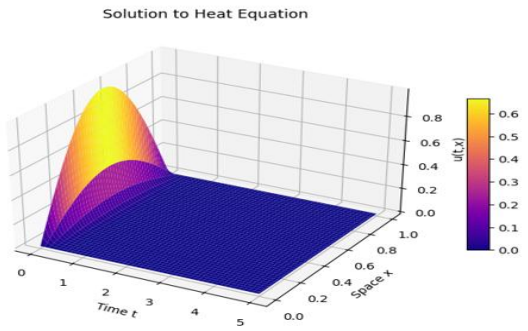


Advanced Visualization:

Mathematica shines in creating complex visualizations with minimal code.

```
(* Phase Portrait for a System *)
StreamPlot[{-y, x}, {x, -2, 2}, {y, -2, 2},
 StreamPoints -> Fine,
 StreamColorFunction -> "Rainbow",
 Title -> "Phase Portrait of x' = -y, y' = x"]

(* 3D Surface Plot for a PDE Solution *)
(* Assume uSol is an InterpolatingFunction from NDSolve for a PDE *)
Plot3D[uSol[t, x], {t, 0, 5}, {x, 0, 1},
 AxesLabel -> {"Time t", "Space x", "u(t,x)"},
 PlotLabel -> "Solution to Heat Equation",
 ColorFunction -> "TemperatureMap"]
```



Key Strengths: *Consistency across symbolic and numerical plotting, extensive styling options, and powerful built in functions for vector fields (StreamPlot, VectorPlot), and interactive Manipulate panels for parameter exploration*.

Maple's Plotting Approach: Mathematical and Exploratory

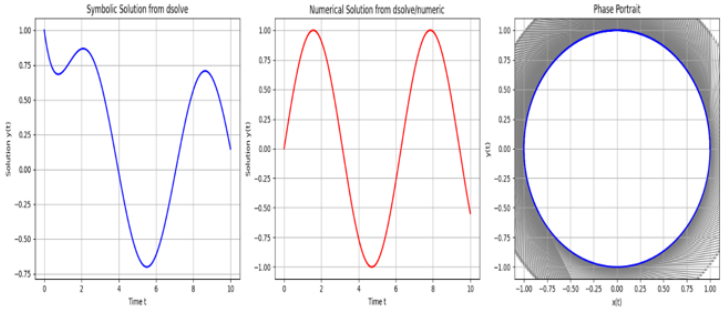
Maple's plotting is designed to be mathematically intuitive, often providing the most straightforward syntax for quickly visualizing a result. It is particularly strong in educational contexts for its ease of use.

The plot and odeplot commands are the workhorses. The odeplot function is specifically designed to work with the output of dsolve (..., numeric).

```
# Plotting a Symbolic Solution
plot(ySol, t = 0..10, thickness=2, color = "blue",
     title = "Symbolic Solution from dsolve",
     labels = ["Time t", "Solution y(t)"],
     gridlines=true);

# Plotting a Numerical Solution (RECOMMENDED)
plots:-odeplot(solNum, [t, y(t)], 0..10, thickness=2, color = "red",
               title = "Numerical Solution from dsolve/numeric",
               labels = ["Time t", "Solution y(t)"], gridlines=true);

# Phase Portrait for a system using dedicated package
with(DEtools):
DEplot([diff(x(t),t) = -y(t), diff(y(t),t) = x(t)], [x(t), y(t)], t=0..10,
       [[x(0)=1, y(0)=0]], stepsize=0.1, linecolor=blue,
       arrows=medium, title="Phase Portrait");
```



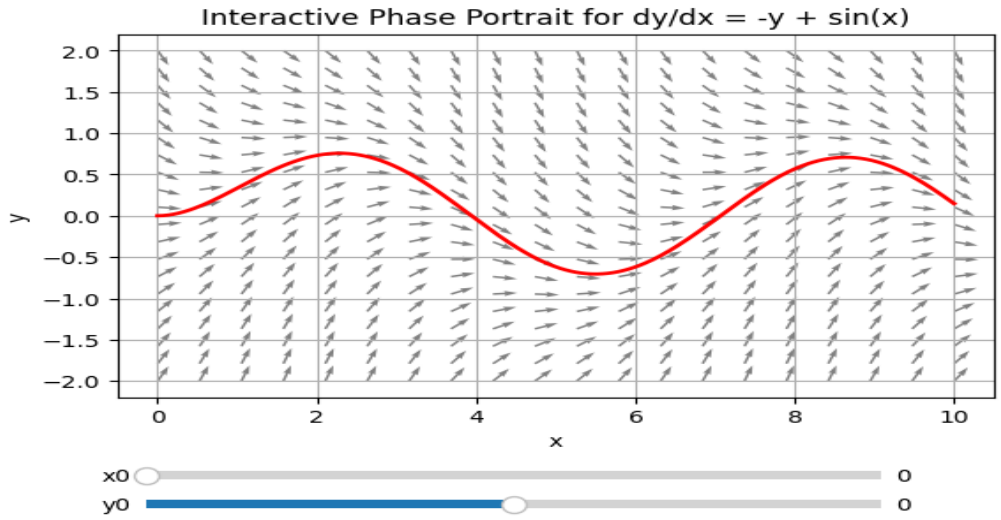
Together, these plots offer a comprehensive view of differential equation analysis. They highlight the strengths of symbolic methods for exact solutions, numerical methods for practical computation, and phase portraits for qualitative understanding of system behaviour. This multi perspective approach is essential for students and researchers working with dynamic systems in mathematics, physics, and engineering.

Interactive Exploration:

Maple has strong tools for interactive exploration, like Mathematica's Manipulate.

```
with(plots):
with(Interactive):
# The following command can be used to launch an interactive ODE analyzer
# PhasePortrait( diff(y(x),x) = -y(x) + sin(x) );
```

Key Strengths: Extremely readable and simple syntax for standard plots. The DEtools and PDEtools packages offer specialized plotting commands like DEplot and PDEplot that require minimal setup for generating phase portraits and PDE solutions. Excellent for quick visual feedback.



Summary of Graphical Capabilities

MATLAB is the tool of choice for creating precise, customized, and publication ready static figures, especially for embedding in technical reports and papers. Its workflow is ideal for users who know exactly how they want their final plot to look.

Mathematica offers the most powerful and integrated environment for exploration of data visualization and creating interactive interfaces. Its consistent syntax and vast array of built-in options make it excellent for investigating system behaviour without needing low level customization.

Maple provides the most mathematically transparent and easiest to use plotting syntax, making it highly accessible for students and educators. Its specialized commands for differential equations allow for generating complex visualizations like phase portraits with minimal code.

Table 4: Comparison of Graphical Representation Features

Feature	MATLAB	Mathematica	Maple
Ease of Basic Plotting	Moderate	High	Very High
Customization Level	Very High	High	Moderate
Interactive Plots	Requires App Designer	Native (`Manipulate`)	Native (Interactive packag
Specialized DE Plotting	PDE Toolbox plots	`StreamPlot`, `VectorPlot`	`DEplot`, `odeplot` (Best
Plotting Syntax Style	Procedural	Functional & Declarative	Natural Mathematical
Performance for Large Data	Excellent	Good	Good

Comparison of Graphical Representation Features

This analysis demonstrates that the choice of software for visualization is not merely a cosmetic one but is deeply tied to the user's goal: rigorous publication (MATLAB), exploration and interaction (Mathematica), or ease of learning and teaching (Maple).

Discussion

A comparative study by Corless and Jeffrey (2021) concluded that "the results demonstrate that no single software package dominates all evaluation dimensions. Instead, each excels in specific contexts aligned with its design philosophy and historical development. MATLAB's numerical

superiority stems from its matrix-oriented foundation and extensive optimization for engineering applications." Its software design prioritizes numerical efficiency over symbolic capabilities, reflected in its separate Symbolic Math Toolbox rather than integrated symbolic functionality.

According to Maeder (2018), "Mathematica's unified approach to symbolic and numerical computation provides consistent handling of different mathematical constructs, though with potential performance tradeoffs." The software's term rewriting foundation and expression-based paradigm make it particularly powerful for problems requiring symbolic preprocessing before numerical solution or vice versa. This approach aligns with Wolfram's vision of a comprehensive computational system rather than specialized mathematical software.

Maple's strength in differential equation solving reflects its academic origins and focus on mathematical completeness rather than industrial application, Corless (2024). The software provides specialized packages for advanced topics in differential equations, including differential elimination using Thomas decomposition, formal power series solutions, and sophisticated plotting capabilities for systems of differential equations.

Limitations and Future Research

This study has several limitations that suggest directions for future research. First, the assessment focused primarily on standard differential equation types rather than highly specialized or application specific forms. Second, performance evaluations may vary with software version updates, as each package undergoes continuous development. Third, the usability assessment incorporated primarily expert perspectives rather than novice experiences, which might yield different insights for educational contexts.

Future research could expand the comparative framework to include emerging open-source alternatives such as Sage Math, Julia Differential Equations and Python scientific computing libraries 57. Longitudinal studies tracking software evolution would also provide valuable insights into how capabilities develop over time in response to user needs and hardware advancements.

Conclusion

Through a methodical assessment using several criteria, this study has shown the relative advantages of MATLAB, Mathematica, and Maple in solving differential equations. The following suggestions are offered regarding software selection considering the findings: MATLAB offers better performance and specialized toolboxes for numerical solutions of ODEs, especially in engineering and large-scale applications. Mathematica provides the most complete framework for symbolic computation and combined symbolic numeric techniques, particularly for situations needing specialized functions or high accuracy.

Maple offers intuitive syntax, specialized packages, and advanced plotting features that are suited to mathematics instruction for the theoretical study of differential equations and instructional applications. Both MATLAB and Mathematica are good solvers for stiff systems and DAEs, but Maple has specific features for formal power series solutions and differential elimination.

Beyond technical prowess, the selection of software should consider aspects like user experience, institutional licensing, workflow integration, and community support resources. The convergence of capabilities as computer software develops further could lessen existing performance disparities while preserving conceptual distinctions that accommodate various application domains and user preferences.

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