WHAT'S NEW

Maple™ 2019

What's New in **Maple 2019**

Maple™ 2019 brings you even more, even stronger mathematical capabilities, from enhancements to the core routines you use every day, to specialized tools that open up new areas of research. In addition, there are advances to the Maple programming language, more education tools, new visualizations, and lots more!

Get More Answers

Maple 2019 includes hundreds of enhancements to the core mathematics you use every day (whether you realize it or not!).

Solve PDEs

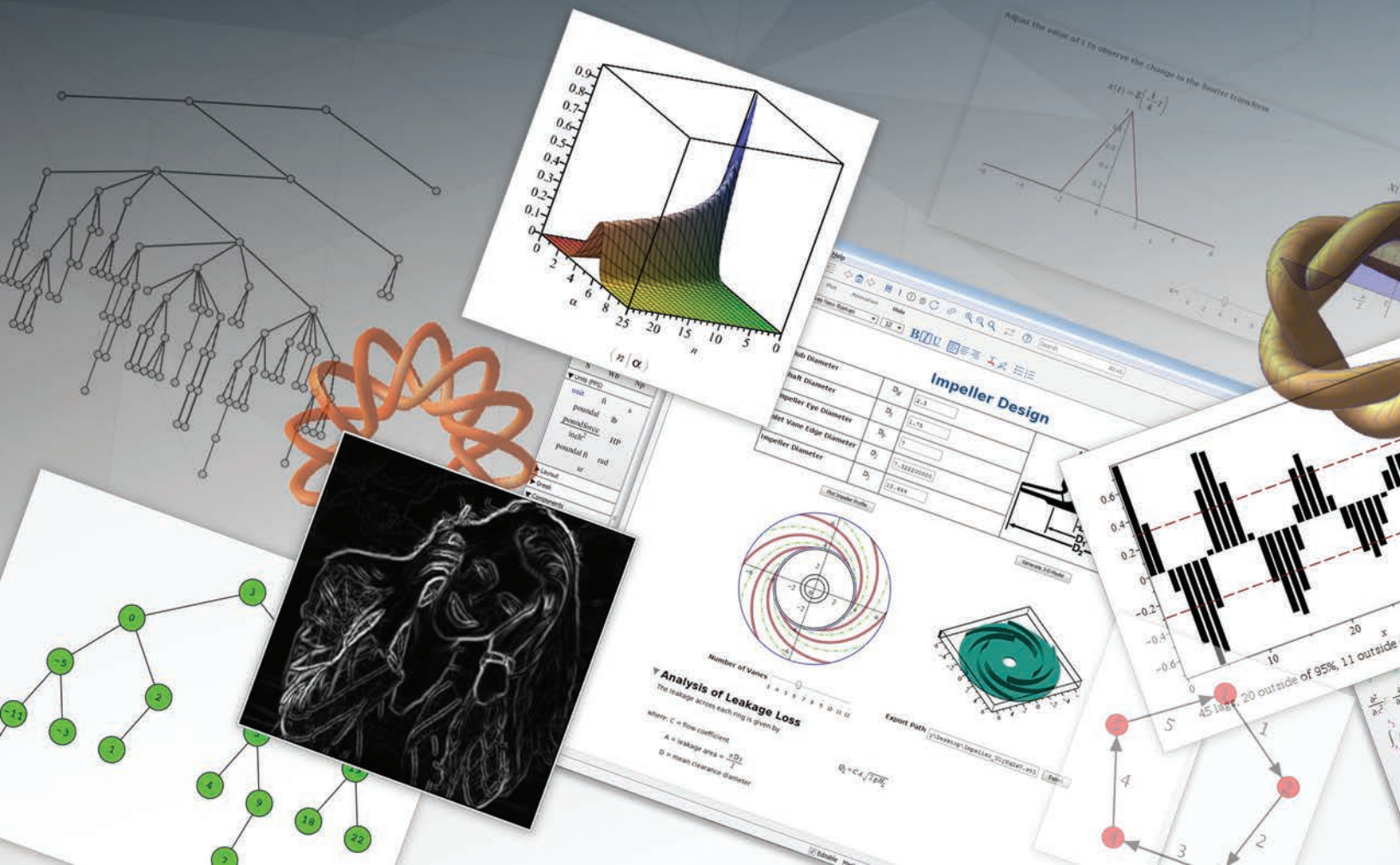
Maple is the clear leader in finding symbolic solutions to partial differential equations, and with Maple 2019, the gap just got bigger!

Analyze Tensors

As a result of the efforts to further strengthen Maple's world leading tools for physics, Maple 2019 is now unmatched when it comes to tensor computations.

Make Groups Less Work

Substantial enhancements in group theory mean you can construct, compute with, and visualize even more groups, in more ways, more efficiently.



Find Meaning in Your Signals

Whether you're removing echo from audio, analyzing the orbital periodicity of exoplanets, or any of the other myriad applications of signal processing, Maple 2019 will help you extract more meaning, faster.

Understand your Data

From better previews of your raw data to new analysis tools, Maple 2019 helps you learn from your data.

Compute with Molecules

The Quantum Chemistry Toolbox from RDMChem, a new Maple add-on toolbox, provides a comprehensive, easy-to-use environment for the parallel computation of the electronic energies and properties of molecules.

Sort Out Sorting (and Other Concepts)

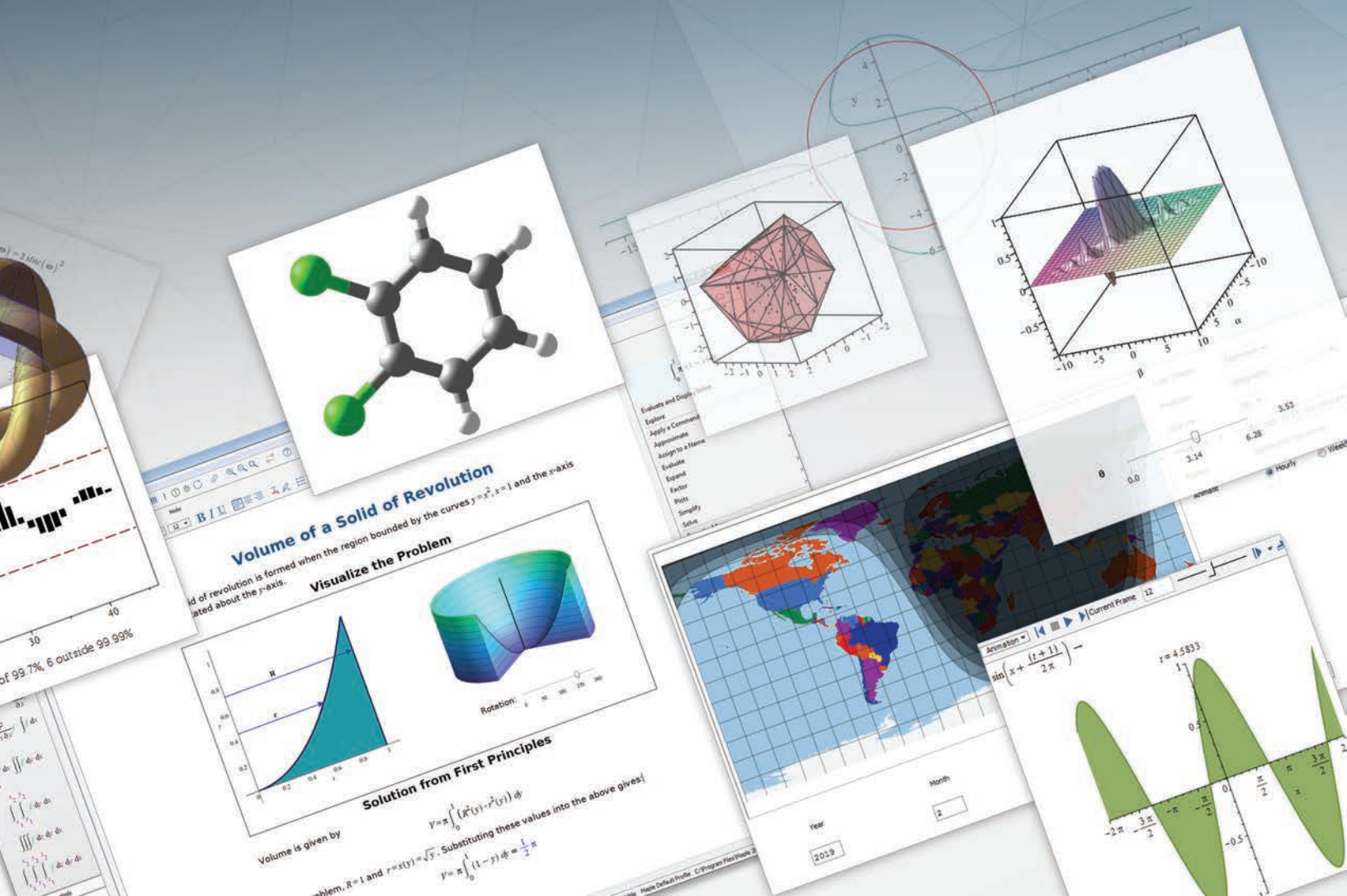
The latest interactive Math Apps help convey important concepts in computer science and more.

Write Efficient Code Efficiently

Maple 2019 includes many enhancements to Maple's language, data structure manipulation utilities, and debugging tools that help you write more efficient code, more efficiently.

Start Out Right

A completely redesigned Start Page, together with an expanded set of user resources, provides a more useful environment for everyone when you open Maple (and you can turn it off more easily if it's not for you).



Advanced Math

Maple 2019 includes a very large number of improvements that strengthen the math engine, increasing the number and type of problems that Maple can solve. In addition to the advancements in PDEs, limits, group theory, tensors, computational geometry, and other topics that are detailed elsewhere, there are also enhancements to fundamental routines that are commonly called on both by customers and by other Maple commands. These include:

- The *simplify* command has undergone several improvements, in particular with regard to expressions containing piecewise functions.
- Improvements to integration mean Maple 2019 can solve more integrals than previously.
- The *solve* command in Maple 2019 has been improved, including enhancements when solving inequalities.
- A new command, *FindODE*, in the *DEtools* package, tries to find a linear ordinary differential equation with polynomial coefficients for the given expression
- The commands for performing Laplace, inverse Laplace, Fourier, and inverse Fourier transforms can handle a larger class of problems, and some classes of problems are handled faster than before.
- A new algorithm for univariate polynomials has been added to the *RootFinding:-Isolate* command, which is particularly efficient for ill-conditioned problems and for finding high-accuracy solutions, and provides certified real root isolation for polynomials with irrational coefficients.
- The *residue* command has a new optional argument that allows the user to specify the maximal order of the underlying series computations.
- *Rationalize* works better on certain examples of nested radicals.
- Expressions with nested calls to *Re* and *Im* now give improved results.
- *Expand*, *floor*, and *ceiling* have more support for assumptions.

Partial Differential Equations

Maple 2019 includes significant improvements that further strengthens Maple's world-leading ability in finding exact solutions to partial differential equations, including additional methods for solving new classes of problems, more flexibility in choosing the methods to try, and improved simplification of the results. Improvements have been made in the following areas:

- PDE and boundary condition problems solved using linear change of variables
- Specifying or excluding methods for solving
- Series solutions for linear PDE and BC problems solved via product separation with eigenvalues that are the roots of algebraic expressions which cannot be inverted
- Superposition method for linear PDE with more than one non-homogeneous BC
- Polynomial solutions method
- Solving more problems using the Laplace transform or the Fourier transform
- Improvements to solving heat and wave PDEs, with or without a source
- Improvements in series methods for Laplace PDE problems
- Better simplification of answers
- Linear differential operator: more solutions are now successfully computed
- More problems in three variables are now solved

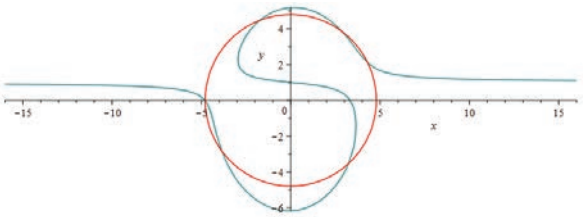
Limits

The *limit* command in Maple 2019 has been enhanced for the case of limits of quotients of multivariate functions. Many such limits that could not be determined previously are now computable. Improvements include handling functions that contain absolute values or radicals, support for functions in more than two variables, and returning ranges in the bivariate case.

Root Finding

The Root Finding package is a suite of advanced commands for finding roots numerically. The routines in this package augment the root-finding functionality provided by *fsolve*, especially with respect to finding several roots concurrently, so all improvements to the Root Finding package automatically result in improvements to *fsolve*.

The *RootFinding:-Isolate* command has been expanded so that it can isolate the roots of univariate polynomials with arbitrary real coefficients, not just rationals or floats. In particular, *Isolate* can now be used to find roots of polynomials with algebraic coefficients.



The new default algorithm of *Isolate* also features vastly improved performance for ill-conditioned polynomials with clustered roots. The root finding method eventually converges quadratically to regions containing roots, rather than just linearly. The same technique allows even more dramatic improvements for root finding requests with high accuracy even on well-conditioned problems.

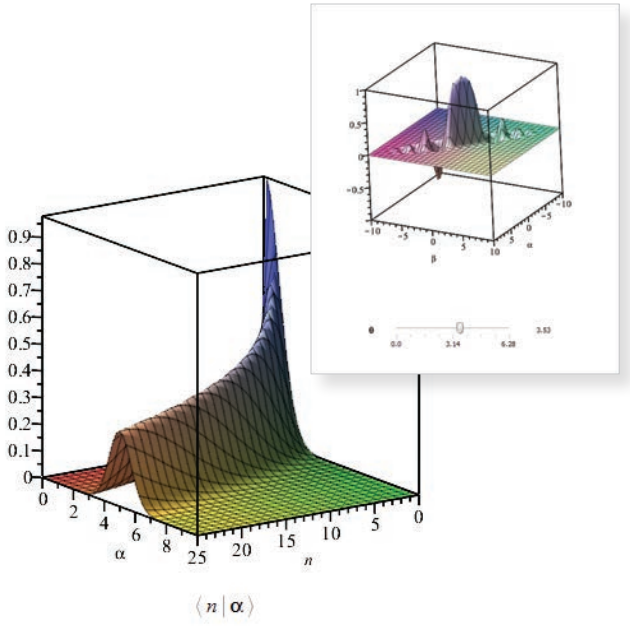
Tensors and Physics

Maple provides a state-of-the-art environment for algebraic computations in physics, with emphasis on ensuring that the computational experience is as natural as possible. Maple 2019 both consolidates the functionality introduced in previous releases, and provides significant enhancements that further strengthen its functionality, especially in quantum mechanics, tensor computations, and documentation.

Highlights from quantum mechanics include coherent states, tensor products of states, Taylor series of expressions involving anti-commutative variables and functions, and several improvements in the normalization and simplification of commutator and anti-commutator algebra rules.

Significant work was done in Maple 2019 to further strengthen, consolidate, and polish Maple's support for tensor computations, making Maple unmatched in the field, covering classical and quantum mechanics, and special and general relativity. In addition, Maple supports natural tensor notation on both input and output, tight integration with the full Maple computation system, and extensive supporting documentation. In particular, *A Complete Guide for Performing Tensor Computations using Physics* is a new e-book included in Maple 2019. This guide covers tensors and their use in Euclidean spaces, special relativity, quantum mechanics, and classical field theory, as well as general relativity and transformations of coordinates on tensorial expressions.

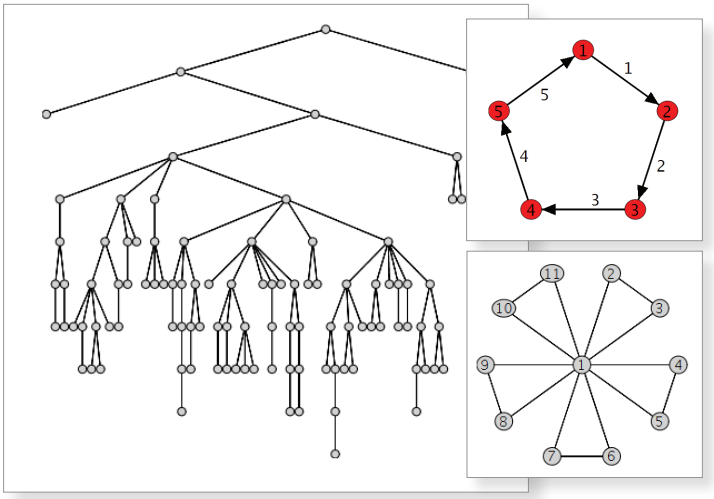
In addition to the new tensor guide, Maple 2019 also includes a mini-course, *Computer Algebra for Physicists*, as well as a new Physics Updates page that consolidates and augments examples, presentations, relevant blog posts, and information from previous updates into a more convenient single page.



Group Theory

The Group Theory package includes an extensive collection of routines for constructing, computing with, and visualizing finitely generated groups, including permutation groups, finitely presented groups, Cayley table groups, "black-box" user defined groups, and abstract groups depending on symbolic parameters. The Group Theory package in Maple 2019 contains more than sixty new or updated commands, new and enhanced databases of groups, and significant performance improvements. New additions include commands for recognizing groups with many interesting properties, new commands for constructing groups of various kinds, new commands to compute subgroups and subgroup series, as well as a suite of commands for recognizing numbers for which every group of a given order has specified group-theoretic properties. Improvements include:

- The new *FindDessins* command computes all dessins d'enfants corresponding to a specified branching pattern, and the *DecomposeDessin* command finds all decompositions of the corresponding Belyi map.
- Maple is now able to recognize finite Frobenius groups, either as abstract groups, or as permutation groups, and to compute Frobenius kernels and complements.
- Several new commands allow you to work with finite Hamiltonian groups.
- New commands enable you to compute various subgroup series and study their properties, including composition series, ordered Sylow towers, and Frattini series.
- The new *DirectFactors* command produces a Remak decomposition of a finite group.
- You can now test whether a finite group has various properties, such as Hamiltonian, Frobenius, directly indecomposable, metacyclic, or if a finite group belongs to various other classes of soluable groups.
- The *SmallGroup* constructor can now construct groups of order *p^k* for arbitrary primes p and positive integers *k* <= 4.



- New number-theoretic commands allow you to determine whether every group of a given order has a specific property, such as cyclic, abelian, soluable, and more.
- Maple 2019 includes a new database of Frobenius groups, along with commands for constructing, identifying, and manipulating them.
- You can now search the database of perfect groups for groups satisfying various combinations of properties, including the order, center, socle, Fitting subgroup, class number and others.
- Many new properties have been added to the databases of small groups and transitive groups.
- Operations on permutation groups are significantly faster and use much less memory.

Graph Theory

The Graph Theory package is a collection of routines for creating, drawing, and manipulating graphs, and for testing graphs for particular properties. New abilities in Maple 2019 include more constructions and properties tests, new special graphs, and many more options for customizing visualizations.

New in Maple 2019, you can find vertex covers, minimum vertex covers, Hamiltonian cycles, and Hamiltonian paths. You can also use greedy algorithms for finding large cliques and

independent sets, perform tests to determine if a graph is strongly regular or triangle free, construct the transitive reduction of a graph, and create Barabási–Albert and Watts-Strogatz random graphs.

Eleven new special graphs or families of special graphs are now supported: Brinkman, Cameron, Circulant, Dürer, Friendship, Hall-Janko, Johnson, Livingstone, Suzuki, Sylvester, and Tietze.

Maple 2019 includes even more ways to customize graph display. For example, graphs look better at non-default sizes, arrows on directed edges use a solid triangle shape and their size and position can be customized, new vertex shapes are available, vertex borders will not overlap, the tree style can be used even if the graph is not a tree, and labels are replaced with pop-up annotations when the graph has many vertices so they are easier to read.

Computational Geometry

Computational geometry problems occur in many applications involving points in two- or higher-dimensional spaces, such as feature recognition, predicting vapor-liquid phase diagrams, delineating closely related regions for scattered data, and more. Maple's Computational Geometry package, which applies computational methods to polygons and clouds of points, has been expanded in Maple 2019, with new tests of properties and computations abilities.

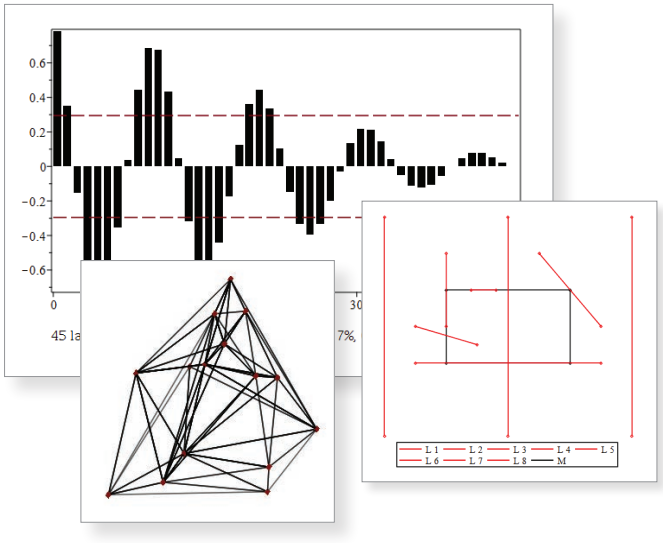
In particular, Maple 2019 includes efficient tests for determining point orientation, if a point lies in a circle or on a line segment defined by other points, if two line segments intersect, or if collections of line segments have intersections. You can also find the closest pair of points in a collection, and the *DelaunayTriangulation* command now supports computing triangularizations in dimensions up to 10.

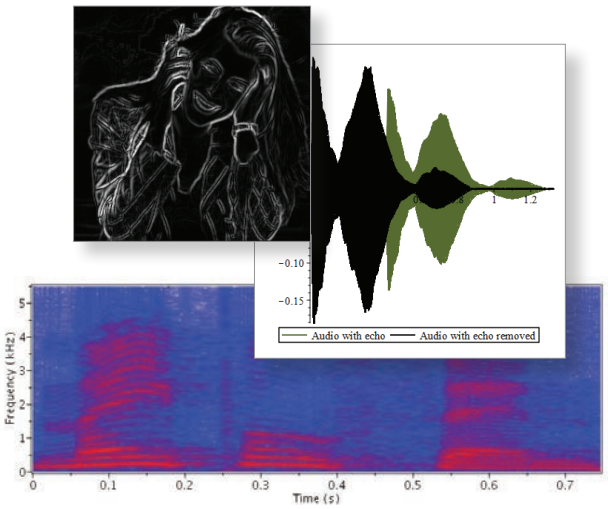
For many commands, you have the option of displaying a graphical representation of the steps of the algorithm.

Statistics and Data Analysis

Maple 2019 offers a variety of improvements for handing, analyzing, and visualizing your data.

- Maple 2019 can now compute least trimmed squares regressions.
- The *Correlogram* command computes autocorrelations of a data set and displays the result as a column plot with dashed lines indicating the lower and upper 95% confidence bands.
- The *Detrend* command removes any trend from a set of data.
- The *Difference* command computes lagged differences between elements in a data set.
- The display of data from large objects, including matrices, data frames, and data series, has been improved so that you can easily view the first few rows and columns of the data.
- Several commands have been updated to support DataFrames and DataSeries, including *remove*, *select* and *selectremove*.
- The *Biplot* command has a new option that enables you to select the principal components used in the biplot.
- The *DataSummary*, *FivePointSummary*, and *FrequencyTable* commands have a new option to control the relative column widths in the resulting table.





Signal Processing

Whether you're removing echo from audio, analyzing the orbital periodicity of exoplanets, or any of the other myriad applications of signal processing, Maple 2019 will help you extract more meaning, faster. In Maple 2019, you can now:

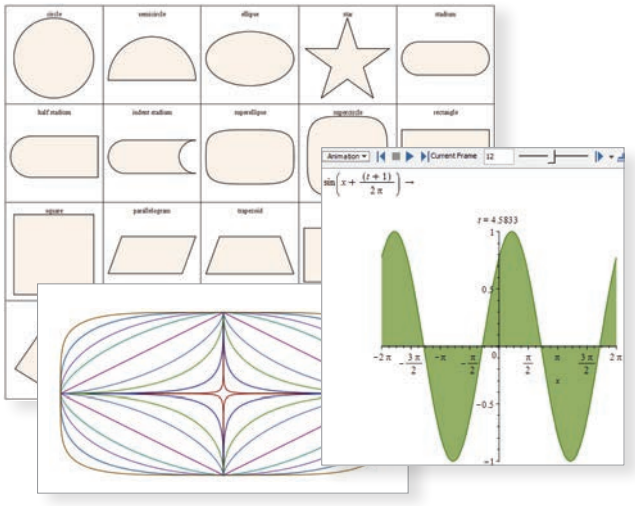
- Generate periodograms of data sampled at irregular time intervals.
- Find the peaks and valleys of 1-D data sets, including filtering out peaks or valleys that are too close, specifying what defines a peak or valley, and more.
- Specify the overlap when generating a spectrogram.
- Calculate the real cepstrum, complex cepstrum and inverse complex cepstrum of a signal.
- Swap data in a matrix or a vector into a different position using the new *FFTShift* command, such as moving the lowest frequencies to the center and the highest frequencies to the corners to produce more meaningful visualizations and simplified manipulations of data.
- Apply an edge detection convolution mask to an image, including Sobel, Robert, Prewitt 3x3, and Prewitt 4x4.
- Calculate the magnitude of the Fourier transform of an image, which can then be embedded as an image to visualize the spatial frequencies of the image.

Dates and Times

Maple can perform calculations involving dates and times, such as analyzing time-dependent data, computing the day of the week of a given date, and taking into account time zones. In Maple 2019, you can easily convert dates and times to strings using a wide variety of formats, and convert date and time strings into their corresponding Maple representation.

Visualization

Maple 2019 enables you to include a wide variety of shapes in your plots, such as circles, squares, triangles, kites, darts, stars, super ellipses, and much more, simply by using the name of the polygon. In addition to the usual plotting options, such as colour and transparency, it also provides many shape-specific options for customization, including rounded corners, rotation, and irregularity. The ability to draw these shapes is very useful for adding annotations to other plots or building more complex 2-D visualizations. For example, it is used by Maple when drawing graphs to render custom vertex shapes.



An important addition to Maple's interactive plotting tools is the extension of the Plot Builder to support animations. In Maple 2019, you can easily create and customize animations using a point-and-click interface, as well as commands.

Other visualization improvements include the introduction of an option for plotting super ellipses and generalized super ellipses, many improvements to the rendering of graphs (described in more detail in the Graph Theory section), the ability to export plots to the Scalable Vector Graphics (SVG) format, and a new correlogram command in the statistic package that displays the autocorrelation of a data set.

Experience on Start-Up

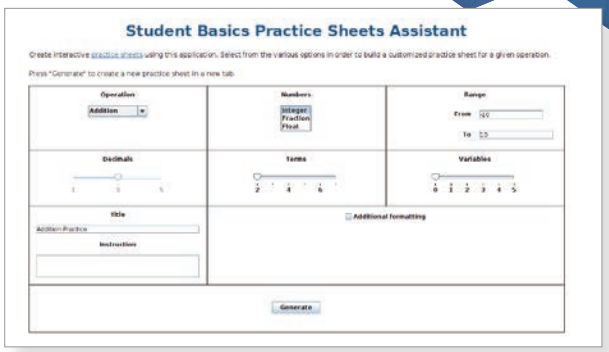
A completely redesigned Start Page, as well as an expanded set of user resources, provides a more helpful environment for everyone when you open Maple

- The Start Page includes new and improved resources designed to help new users get started quickly, including a short introductory video.
- For more experienced users, the Start Page has been simplified to focus on the most helpful, frequently used resources.
- The Maple Portal, a comprehensive resource for any user, has been expanded to present both in-product and web-based resources, organized by preferred learning style.
- For those who would prefer to start from a blank document, it is now significantly easier to turn the Start Page off.

Student Resources

Maple contains many tools designed explicitly to help students learn new ideas, explore concepts, and solve problems, all in an easy-to-use environment. Maple 2019 includes several additions to student-specific resources, including:

- Many more operations from Numerical Analysis can now be performed at the click of a button using menus in the context panel, such as computing the rate of convergence of a sequence or function, finding Taylor polynomial approximations, computing the limit of a vector, calculating the relative error, and more.



- A new assistant makes it easier to create randomly generated and automatically graded practice sheets, for drilling problems in arithmetic, algebra, calculus, factorization and more.
- New interactive Math Apps help students understand important concepts from computer science, such as sorting algorithms and big O notation, as well as topics from other fields.

Performance

Performance improvements in Maple 2019 include both broad-based and targeted enhancements. The following operations are all faster in Maple 2019:

- Maple 2019 includes significant performance improvements for factoring sparse multivariate polynomials with integer coefficients, an operation that is often performed by commonly used higher level routines.
- The *MaximumClique* function of the Graph Theory package has new algorithms for computing the maximum clique of a graph, and an option to choose the algorithm that you want to use, giving a huge performance boost on certain kinds of graphs.
- In the Group Theory package, arithmetic and other low-level operations for permutations have been completely re-written in compiled kernel code to make them significantly faster, and the memory overhead of permutations has been considerably reduced.
- The *RootFinding:-Isolate* command has a new algorithm for univariate polynomials that is dramatically faster for certain classes of ill-conditioned problems, and when requesting solutions with a high number of digits of accuracy.

Interface

Maple 2019 includes a variety of improvements to the interface to improve your workflow.

- Maple 2019 makes it much easier to get a sense of the contents of large matrices, vectors, arrays, data frames, and data series, by displaying the first 10 rows and 10 columns of the data, as well as the size of the structure.
- The new Units by Dimensionality palette expands the number of available unit templates and makes it easier to find units associated with physical dimensions.
- The entries in the Favorites palette can be easily rearranged by clicking and dragging, and in addition, you can now create custom entries.
- New options to the interface command give more control over the display of procedures, colors of output when using the command-line interface, and more.
- Various menus and toolbars have been simplified.
- More operations from the Student Numerical Analysis package can be performed using the context panel.

Maple Language and Programming

Maple 2019 includes many enhancements to the Maple language, data structure manipulation utilities, and debugging tools.

The Maple language now supports:

- Two variables in a for-loop, allowing, for example, the ability to iterate over a matrix's values while also keeping track of the indices of the entry
- Using assignments, if- statements, try- statements, and loops in expressions
- C-style increment, decrement, and assignment operators
- More flexibility in the location of the declarations of local, global, and exported variables in procedures and modules
- Local variable declarations in operator procedures, which are defined using arrow notation
- Efficient mutable strings
- An expended set of valid characters for symbolic neutral operators

Other improvements to programming include:

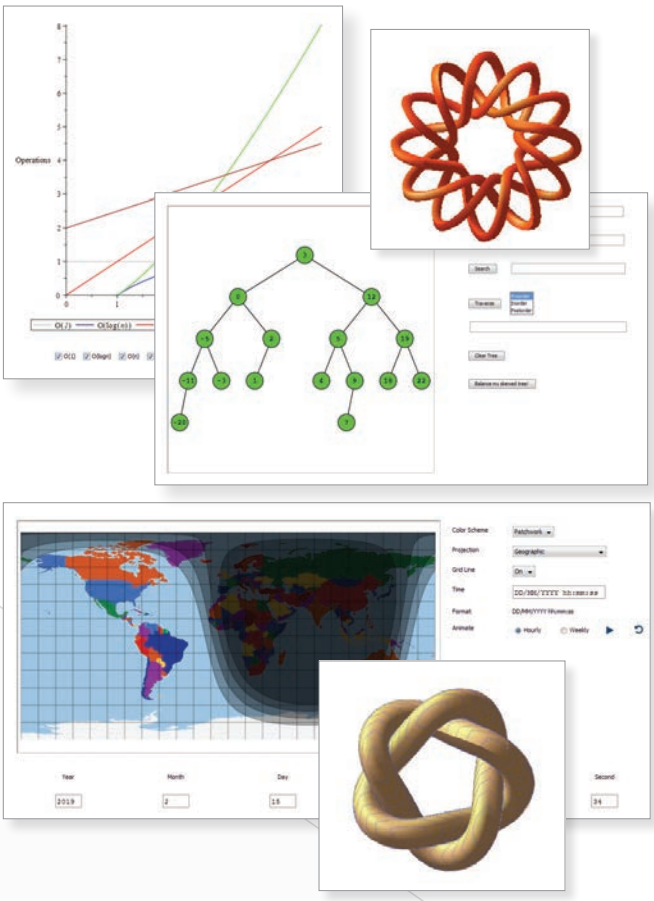
- The *Download* command now makes it possible to download data from a URL to a local file.
- *ArrayTools* has new commands for partitioning, removing and reversing entries.
- The *tablereverse* function takes a table and returns a new table that is a reversal of the initial table.
- The *convert/english* command now allows for round-tripping of integer to English conversions.
- New kernel options provide more detailed feedback on assignments when tracing.
- New interface options offer color syntax highlighting of output, customizing printed procedures, more feedback on errors when running scripts, and session logging.
- The command-line interface adds several new facilities for interactively manipulating, replaying, saving, and restoring the history of commands entered into Maple.
- The *mint* utility now has an option to generate a "ctags" format file, which can be used by many text editors to quickly bring you to the implementation of a given procedure, as well as the ability to produce color-coded output.
- Enhancements to the debugger include improved output from *showstat*, with respect to the display of long lines, the ability to open the source file at the line where the error occurred, and easier access to help on debugger commands.

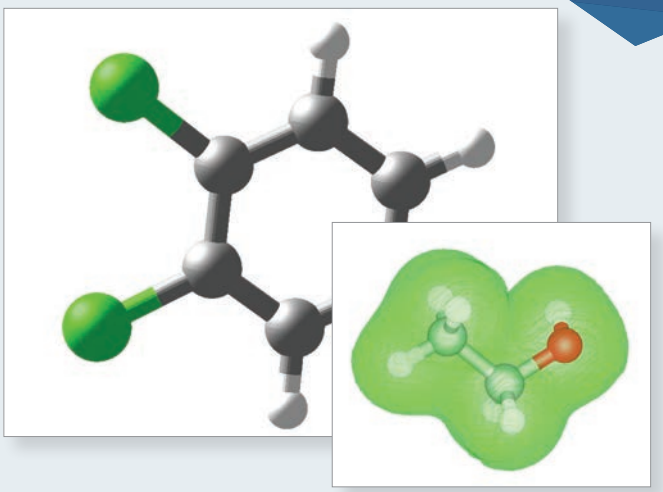
Math Apps, Applications, and Examples

Maple 2019 includes many new interactive Math Apps, examples, and applications, which you can use to explore concepts, learn about new features, discover different ways of applying Maple, and as a starting point for your own work.

New Math Apps include interactive explorations for important ideas from computer science, such as sorting algorithms, big O notation, binary search trees, and stacks and queues. Other new Math Apps cover the law of cosines, triangular functions, night and day terminators, and more.

New applications include visualizing knots, a tutorial on important tabular data, and a detailed example explaining how to create context menus for your own Maple packages.





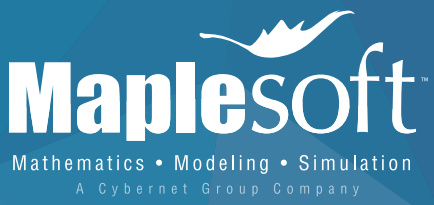
New Add-on! Quantum Chemistry

The Maple Quantum Chemistry Toolbox from RDMChem, a new add-on toolbox for Maple 2019, provides a comprehensive, easy-to-use environment for the parallel computation of the electronic energies and properties of molecules. With this toolbox, you can:

- Define molecules instantly from a database of more than 96 million molecules.
- Run quantum computations with well-known electronic structure methods as well as recently developed, advanced methods for cutting-edge research.
- Analyze molecular energies and properties through publication-quality, 2-D and 3-D plots and animations.

While conventional wave function methods scale exponentially with the size of the molecule, this toolbox achieves a low, polynomial computational scaling through recently developed reduced density matrix (RDM) methods. These methods enable the computation of strongly correlated molecules and materials that were previously inaccessible. They are capable of providing chemists, physicists, and materials scientists with the ability to predict and design novel molecules and materials for applications across the sciences.

This toolbox is available from Maplesoft as a separate add-on product.



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