Application Briefs

Mooring of Two Ships

The mooring of ships to harbors, terminals, and offshore structures is a common and essential procedure in most seafaring operations. Inadequate mooring can result in significant structural damage to the berthing vessel and moorings. To this day, most mooring operations are still performed in the same manner as they were decades ago; they are dependent on heuristics, or in other words, the captain or mooring master's experience. Unfortunately, the effects of global warming and climate change are altering the hydrodynamics of the sea, making manual mooring operations a very risky venture.

The challenge:

To design a mechanism to control and automate a mooring system between two ships at sea.

The engineer uses MapleSim and Maple to:

- Create a physical model of the two ships and mooring cables
- Develop a realistic model of the external environmental forces and use the results to simulate conditions at sea
- Design and tune an appropriate controller to stabilize the system

Developing a realistic model of the external forces was critical to the design of the controller. This allowed the engineer to tune the controller, eliminate vibrations, and stabilize the tension in the line. With the initial control system complete, further improvements can be made to the disturbance model by including additional factors such as wind gusts, and the interaction effects from passing ships.

A Novel Approach to Stabilize the Re-Entry Path of a Space Shuttle

Stability analysis is a vital stage in the design and development process of a control system, providing information about the stability of the system and insight into its operating conditions. In the case of identifying the control parameters required to stabilize the re-entry path of a space shuttle into the earth's atmosphere, most control engineers typically apply a brute-force trial-and-error approach despite the existence of advanced methods, such as one developed by Chang and Han in 1989 that follows a more systematic approach. Although it is extremely precise, this method has not gained much popularity due to the difficult nature of the equations and the inability of traditional software to solve the equations symbolically.

The challenge:

To control the re-entry path of a space shuttle by calculating and examining the stability boundaries of constant gain and phase margins.

The engineer uses Maple to:

- Create a closed loop model of the system with the addition of a gain-phase margin tester
- Symbolically manipulate the closed-loop transfer function equations into the desired form and create a procedure to automatically generate values of the unknown parameters
- Create stability boundary plots for constant gain and margins

Adding the gain-phase margin tester allows the engineer to immediately calculate the control parameters necessary to stabilize the space shuttle within the specified design constraints. By utilizing Maple, the engineer can easily perform the required algebraic manipulations that would otherwise be too complex to do by hand or with purely numeric software. This saves the engineer time by providing the solutions immediately, avoiding the countless iterations required by traditional brute-force methods that could take days to perform.

Key Features

Maple™ 13

Interface

- Technical document environment with live math
- Natural math notation, command completion, context-sensitive self-documenting menus, and syntax highlighting
- Automatic equation numbering
- Dials, sliders, buttons, and other embedded components
- Word processing tools
- Task assistants and templates for common operations
- Fully integrated electronic help and printed manuals

Math and Visualization

- Over 4000 symbolic and numeric functions
- The world's best ODE, PDE, and high-index DAE solvers
- Coverage of virtually every area of math, including differential equations, integral and discrete transforms, statistics, matrix computation, signal processing, optimization, and more
- Units and tolerance management
- Wide range of customizable 2-D and 3-D plots

Connectivity

- Royalty-free C, Fortran, Visual Basic™, MATLAB®, and Java™ code generation
- Connectivity with Autodesk Inventor®, SolidWorks®, NX®, Excel®, and MATLAB®
- Open API – use Maple as an engine in custom applications, or use external code libraries within Maple
- Built-in export to HTML, RTF, PDF, and many other data formats

MapleSim™ 3

Interface and Modeling

- Drag-and-drop block diagram modeling environment
- Signal-flow blocks and multidomain physical components
- Units-aware
- Masked subsystems to manage model hierarchy
- Library of models across multiple disciplines

Simulation

- Stiff/non-stiff and fixed/adaptive step numerical solvers
- DAE index reduction and analytic solution of algebraic loops without user intervention
- Compiled run-time mode and equation caching for rapid execution
- Linear, nonlinear, continuous, and discrete time, SISO, MIMO, and hybrid systems
- C-code generation for real-time applications

Analysis and Documentation

- Extract, analyze, and document the system equations in Maple
- Maple templates for control analysis, creating custom components from mathematical equations, generating data sets, equation generation and manipulation, optimization, Monte-Carlo Simulation, and sensitivity analysis
- Full access to Maple for simulation analysis, visualization, and design documentation

Visualization

- Customizable 2-D plots and full range of plots from Maple
- Automatically generate 3-D animations of multibody systems, and include imported CAD models
- Pan, zoom and scale, point-probe, drag-and-drop traces
- Export plots to external files

Add-on Products and Toolboxes

Maple™ Toolbox *for* MATLAB®

A technical computing solution that is tightly integrated with MATLAB, providing direct access to all the commands, variables, and functions of each product while working in either environment.

Maple™ Global Optimization Toolbox

Formulate your optimization model easily inside the powerful Maple numeric and symbolic system, and then use world-class Maple numeric solvers to return the best answer, fast!

Advanced Engineering Mathematics

Part of the Maple Interactive E-book Collection, Advanced Engineering Mathematics is the definitive reference software and textbook for engineering mathematics.

MapleSim™ Simulink® Connector

Automatically convert high-performance, high-fidelity MapleSim models to S-Function blocks for seamless inclusion in Simulink diagrams.

MapleSim™ LabVIEW™ Connector

Extend your LabVIEW applications by integrating MapleSim's high-performance, multi-domain environment into your existing toolchain. Optimized MapleSim models give you performance you need for hardware-in-the-loop (HIL) testing without sacrificing fidelity.

MapleSim™ Control Design Toolbox

A solid set of essential control design tools that extends MapleSim's exceptional plant modeling capabilities to support control design.

Additional Products and Services

- Grid Computing Toolbox
- Training & Consultancy
- Maintenance and support

For more add-ons, visit www.maplesoft.com/products

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Mathematics • Modeling • Simulation

www.maplesoft.com | info@maplesoft.com
Toll-free: (US & Canada) 1-800-267-6583 | Direct:1-519-747-2373

Maplesoft Engineering Suite

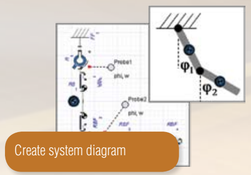
A New Generation of Software Tools for the Engineering Professional

- Engineering Calculations and Design Documentation
- Optimization and Analysis
- Application Deployment and Connectivity
- Physical Modeling and Simulation
- Real-Time Simulation and Hardware-in-the-Loop Applications

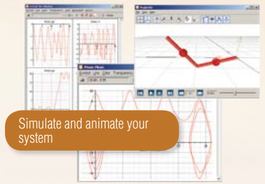
MapleSim™ 3

High-Performance Multi-Domain Modeling and Simulation

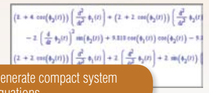
From Concept to Completion



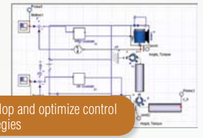
Create system diagram



Simulate and animate your system



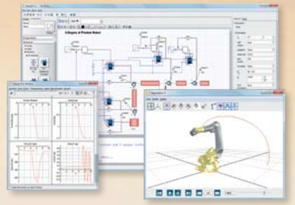
Generate compact system equations



Develop and optimize control strategies

Generate optimized code for high performance real-time simulation

MapleSim™ is the leading physical modeling tool that helps you meet the challenges of complex physical modeling projects. It is the ideal software package for developing models for multi-domain engineering systems, including sophisticated plant models for control systems development. MapleSim's intuitive physical modeling environment offers a powerful and flexible set of tools, which dramatically extends your modeling capacity. In addition to supporting rapid model development, MapleSim produces highly optimized equation-based models to provide the best possible real-time performance for hardware-in-the-loop (HIL) applications. Built on a foundation of the world's most powerful symbolic computation engine, MapleSim offers the most extensive range of advanced analysis tools, supporting sensitivity analysis, optimization, and advanced visualization techniques. With MapleSim, you will produce better, faster models and dramatically shorten your product development cycle.



Mix physical components with signal-flow blocks. Rapidly build plant models that use physical components and prototype controller loops using signal-flow blocks, all in one environment.

Model diagrams map onto the real system. With MapleSim, you avoid having to derive and manipulate system equations into signal-flow block diagrams. Simply re-create the system diagram on-screen using components that represent the physical model. Validation is fast because the model maps onto the real system.

System equations are automatically generated and optimized. MapleSim uses powerful symbolic techniques to generate model equations in a form you can view, document, and analyze in Maple. Complex models are simplified and streamlined, resulting in very compact, numerically efficient models that run significantly faster than in other simulation systems.

Powerful analysis and documentation tools. MapleSim is tightly integrated with the Maple environment. Built-in Maple templates help with analysis, creating custom components, optimization, code generation, and more. Live design documentation ensures that processes and design constraints are documented in a math-aware environment.

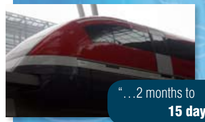
3-D animation delivers immediate insight. MapleSim automatically generates 3-D visualizations of multibody systems to help validate the physical geometry of your model. Animation then gives you immediate insight into the kinematic and dynamic behavior of your model.

"MapleSim saved me many hours of work because the model maps onto the topology of the physical system and the dynamic equations do not have to be developed by hand. This also enables very complex multi-disciplinary system models to be built and analyzed by a single person. MapleSim converts a painstaking and laborious process into one that is simple and enjoyable."

Dr. Richard Gran, President and CEO of The Mathematical Analysis Company

From months to days

Maple and MapleSim are quickly becoming the tools of choice for model development in industry and research as the technology literally collapses your project time from months to days.

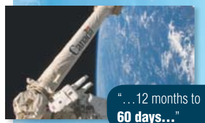


"…2 months to **15 days…**"

Maglev Train Controller Design
A designer created a dynamic model of new magnetic drive system and developed the control system for a smoother and more comfortable ride.

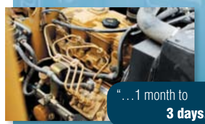
"…3 months to **10 days…**"

Dynamic Model of a Hybrid Electric Vehicle
A team produced a full-vehicle dynamic model for studying the effects of retrofitting a hybrid drive into an existing vehicle platform for real-time simulation.



"…12 months to **60 days…**"

Multi-degree-of-freedom Flexible-Arm Robot for Space Applications
Researchers produced a high-fidelity real-time simulation of a 15-DOF flexible-arm robotic platform for training and task planning.



"…1 month to **3 days…**"

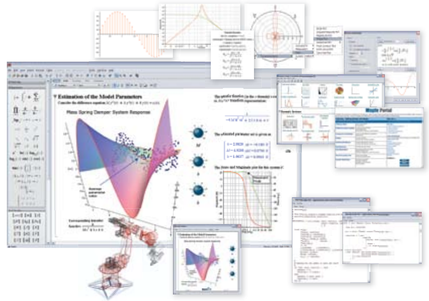
Analysis of Engine Vibration in a Diesel Engine
An engineer analyzed a lumped-parameter model to identify and address conditions that produced severe vibrations on engine shut-down, without resorting to FE analysis.

Maple™ 13

The Essential Tool for Mathematics and Modeling

Maple™ 13 delivers a broad suite of math and analysis tools in an interface that scales easily from quick design calculations to full application development. From the world's most robust math engine and live design documentation to CAD connectivity and code generation, Maple supports all stages of the design lifecycle.

Powerful Math Engine. The core math engine delivers a broad suite of symbolic and numeric solvers. This includes tools for matrix computation, differential equation solvers, code generation, data analysis, optimization, statistics, and much more.



Ease of Use. Maple's remarkably intelligent interface minimizes the learning curve through context-sensitive menus, command completion, templates, palettes, and natural math notation. This makes Maple ideal for everything from quick calculations and design deliverables to full application development with custom interfaces.

Compelling Visualization. Rapidly generate a broad range of customizable 2-D and 3-D plots, including plots for controls analysis using context-sensitive and interactive plot builder menus. Exploit the programmatic interface for complete control over every aspect of your graphs.

Live Design Documentation. Maple offers a complete array of document layout and word processing tools that enable you to document as you design. You can do your calculations and produce a deliverable in a single environment.

Extensive Connectivity. Code generation, external calling, an open API, and CAD, MATLAB®, Excel®, database, and network connectivity means that Maple amplifies the investment you made in other tools.

"In comparison with others, Maple can do in a couple of hours what other software can take days to compute. The natural math notation allows me to enter the equations as if I were writing them by hand. The fact that I can do symbolic calculations allows me to do optimizations that are virtually impossible with other software. What's more, the results are extremely accurate."

Jean-Louis Ligier, Research and Development Manager, Renault

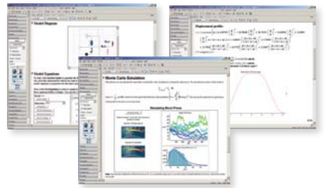
Exclusive Maplesoft Technologies

Symbolic and Numeric Math Tools
For automated model equation generation, optimization, and simulation

Maplesoft's core symbolic and numeric technology has evolved over a period of 25 years and is now considered the finest math functionality in the world. Technical professionals across the world have exploited tools for differential equations, matrix computation, optimization and statistics, and more using Maple's technical document interface.

Now, MapleSim uses the same core algorithms to automate much of the traditional human effort required to manually derive system equations. Symbolic technology eliminates redundant equations and problematic elements such as algebraic loops, and resolves complexities incurred by differential-algebraic equations. Then, powerful numeric solvers process the system description for the final simulation results. Finally, the resulting model can be analyzed with the full range of math tools within Maple.

Example of equation simplification: from 2300 equations to 150, 10x speedup on execution with no loss of fidelity.

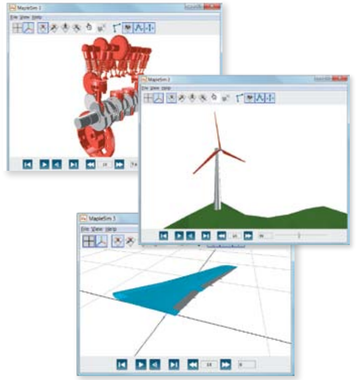


Interactive Document Interface
For minimal training costs and a low learning curve

The Maple 13 document-centric environment combines easy access to all the mathematical and graphical power of Maple with a complete set of document processing tools. You can create live design documents and deliverables, and create shareable applications with custom interfaces, all within a single environment.

Multibody Dynamics
For fast, efficient, multibody simulations

Cutting-edge fields such as mechatronics, robotics, biomechanics, and vehicle dynamics demand high-fidelity models of multibody systems. The MapleSim engine for multibody dynamics is based on proprietary graph-theoretic formulation techniques that produce models with performance, compactness, and usability significantly better than other physical modeling systems.



Code Generation
For high-speed, real-time models

You can generate code for hardware-in-the-loop applications from the highly optimized models generated in MapleSim. This code runs many times faster than code produced in traditional tools, and enables you to implement real-time versions of models that would otherwise be impossible.