

cubic spline interpolation matlab

cubic spline interpolation matlab is a powerful technique widely used in numerical analysis and scientific computing to construct smooth curves that pass through a set of data points. MATLAB, a high-level programming environment, offers robust tools and functions to implement cubic spline interpolation efficiently. This article explores the concept of cubic spline interpolation, its implementation in MATLAB, and practical applications, providing a comprehensive guide for beginners and experienced users alike.

Understanding Cubic Spline Interpolation

What Is Cubic Spline Interpolation?

Cubic spline interpolation is a method for estimating unknown data points within the range of a discrete set of known data points. Unlike linear interpolation, which connects points with straight lines, cubic spline interpolation employs piecewise cubic polynomials that ensure a smooth and continuous curve. The main advantages of cubic splines include:

- Smooth first and second derivatives
- No sharp corners or discontinuities at data points
- Better approximation of underlying functions

Mathematical Foundation of Cubic Splines

Given a set of data points $((x_0, y_0), (x_1, y_1), \dots, (x_n, y_n))$, the goal is to find a set of cubic polynomials $(S_i(x))$ such that:

- $(S_i(x))$ interpolates the data points within each interval $[(x_i, x_{i+1})]$
- The entire spline $(S(x))$ is continuous, with continuous first and second derivatives

Each $(S_i(x))$ is typically expressed as:

$$S_i(x) = a_i + b_i (x - x_i) + c_i (x - x_i)^2 + d_i (x - x_i)^3$$

where the coefficients (a_i, b_i, c_i, d_i) are determined by solving a system of equations derived from the interpolation conditions and boundary conditions.

Implementing Cubic Spline Interpolation in MATLAB

MATLAB simplifies the process of cubic spline interpolation through pre-built functions, enabling users to perform complex interpolations with minimal code. The key functions include:

- `spline()`: Creates a cubic spline interpolant
- `ppval()`: Evaluates the spline at specified points
- `csape()`: Performs cubic spline interpolation with additional boundary conditions (from the Curve Fitting Toolbox)

Basic Usage of `spline()` Function

The `spline()` function constructs a piecewise polynomial structure based on data points.

```
```matlab
% Sample data points
x = [0, 1, 2, 3, 4, 5];
y = [0, 0.8, 0.9, 0.1, -0.8, -1];

% Create cubic spline interpolant
pp = spline(x, y);

% Evaluate spline at dense points for smooth plotting
xx = linspace(min(x), max(x), 100);
yy = ppval(pp, xx);

% Plot original data and interpolated curve
plot(x, y, 'o', xx, yy, '-');
title('Cubic Spline Interpolation in MATLAB');
xlabel('x');
ylabel('y');
legend('Data Points', 'Spline Interpolation');
grid on;
```
```

This simple example demonstrates how MATLAB's `spline()` function constructs the interpolant, which is then evaluated with `ppval()`.

Handling Boundary Conditions

By default, MATLAB's `spline()` uses "not-a-knot" boundary conditions, which ensure the spline behaves naturally at the endpoints. However, in some applications, you may need to specify different boundary conditions, such as:

- Clamped (specified first derivatives)
- Natural (second derivatives at endpoints are zero)
- Complete (derivatives specified at both ends)

For such cases, MATLAB's `csape()` function from the Curve Fitting Toolbox allows more control.

```
```matlab
% Example with natural boundary conditions
pp = csape(x, y, 'variational');
```
```

Practical Applications of Cubic Spline Interpolation in MATLAB

Cubic spline interpolation is used across various domains:

- Data smoothing: Removing noise from experimental data
- Curve fitting: Modeling complex relationships
- Image processing: Resampling and resizing
- Computer graphics: Path animations and shape modeling
- Engineering simulations: Interpolating physical parameters

Example: Interpolating Experimental Data

Suppose you have temperature measurements at specific times and want a smooth curve to analyze trends.

```
```matlab
times = [0, 2, 4, 6, 8, 10];
temperatures = [15, 20, 22, 21, 19, 16];

% Create spline interpolant
temp_spline = spline(times, temperatures);

% Generate fine time points
fine_times = linspace(0, 10, 200);
temp_fine = ppval(temp_spline, fine_times);

% Plot data and interpolation
plot(times, temperatures, 'o', fine_times, temp_fine, '-');
title('Temperature Data Interpolation using Cubic Splines');
xlabel('Time (hours)');
ylabel('Temperature (°C)');
legend('Measured Data', 'Spline Interpolation');
grid on;
```
```

This approach provides a smooth curve that can be used for further analysis or visualization.

Advanced Topics in Cubic Spline Interpolation with MATLAB

Customizing Spline Behavior

Beyond basic interpolation, MATLAB allows customizing the spline's behavior through boundary conditions, spline smoothing, and piecewise polynomial manipulation.

Smoothing Splines

Sometimes data contains noise, and a smooth approximation rather than exact interpolation is desired. MATLAB's `spaps()` function performs smoothing spline fitting:

```
```matlab
% Data with noise
x = linspace(0, 10, 50);
y = sin(x) + 0.2*randn(size(x));

% Smoothing spline with specified smoothing parameter
[sp, ~] = spaps(x, y, 1e-2);

% Evaluate and plot
xx = linspace(0, 10, 200);
yy = fnval(sp, xx);
plot(x, y, 'o', xx, yy, '-');
title('Smoothing Spline in MATLAB');
xlabel('x');
ylabel('y');
legend('Noisy Data', 'Smoothed Spline');
grid on;
```
```

Note: Smoothing splines do not necessarily pass through all data points but provide a smooth approximation.

Piecewise Polynomial Manipulation

MATLAB's `mkpp()` and `ppform()` functions allow for direct manipulation of piecewise polynomial structures, useful in advanced applications.

Tips for Effective Cubic Spline Interpolation in MATLAB

- Ensure data points are sorted in increasing order of x for proper spline construction.
- Use `linspace()` to generate dense evaluation points for smooth plots.
- Verify boundary conditions to match the physical context of your data.
- For noisy data, consider smoothing splines to avoid overfitting.
- Leverage MATLAB's visualization tools to assess the quality of your interpolation.

Conclusion

Cubic spline interpolation in MATLAB is a versatile and essential tool in numerical analysis, data science, and engineering. Its ability to produce smooth, continuous curves passing through data points makes it ideal for modeling complex phenomena accurately. MATLAB's built-in functions like `spline()`, `ppval()`, and `csape()` simplify the implementation process, allowing users to focus on

analysis and application. Whether you're smoothing noisy experimental data, modeling physical systems, or creating smooth animations, understanding and utilizing cubic spline interpolation in MATLAB enhances your analytical toolkit significantly.

Keywords: cubic spline interpolation, MATLAB, `spline()`, `ppval()`, curve fitting, data smoothing, numerical analysis, interpolation, boundary conditions, smoothing splines

Frequently Asked Questions

How do I implement cubic spline interpolation in MATLAB?

You can use the built-in `'spline'` function in MATLAB. For example, given data points x and y , use $y_i = \text{spline}(x, y, x_i)$ to interpolate at points x_i . Additionally, functions like `'csape'` from the Curve Fitting Toolbox provide more control over spline types.

What is the difference between `'spline'` and `'pchip'` in MATLAB?

The `'spline'` function computes a cubic spline with natural boundary conditions, resulting in a smooth curve with continuous first and second derivatives. `'pchip'` (Piecewise Cubic Hermite Interpolating Polynomial) preserves the shape and monotonicity of data, avoiding overshoot, making it suitable for data with sharp features.

How can I visualize cubic spline interpolation results in MATLAB?

After computing the interpolated values using `'spline'`, plot your original data points and the interpolated curve using the `'plot'` function. For example: `plot(x, y, 'o', xi, yi, '-')`; hold on; to compare the original data and the spline interpolation visually.

Can I control the boundary conditions in MATLAB's cubic spline interpolation?

Yes, MATLAB's `'csape'` function allows you to specify various boundary conditions, such as `'not-a-knot'`, `'second'`, `'periodic'`, or `'clamped'`. This gives you control over the spline's behavior at the endpoints based on your data requirements.

What are common applications of cubic spline interpolation in MATLAB?

Cubic spline interpolation is widely used in data smoothing, curve fitting, image processing, and numerical solutions of differential equations where smooth curves passing through data points are needed.

How do I handle large datasets efficiently with cubic spline interpolation in MATLAB?

For large datasets, precomputing the spline coefficients with 'spline' or 'csape' and then evaluating the spline at multiple points is efficient. Avoid recomputing the spline repeatedly; instead, store the spline structure and evaluate it as needed.

What are the limitations of cubic spline interpolation in MATLAB?

Cubic spline interpolation can exhibit Runge's phenomenon with highly oscillatory data or unevenly spaced points, leading to unwanted oscillations. It may also produce overshoot or undershoot near steep data changes. In such cases, alternative methods like shape-preserving interpolants might be more appropriate.

Additional Resources

Cubic Spline Interpolation MATLAB: An In-Depth Examination of Methodology, Implementation, and Applications

Interpolation is a fundamental technique in numerical analysis, enabling the estimation of values between known data points. Among various interpolation methods, cubic spline interpolation stands out for its ability to produce smooth, continuous curves that accurately model real-world phenomena. When implemented in MATLAB, a high-level language and computing environment widely used in engineering and scientific research, cubic spline interpolation becomes an accessible yet powerful tool for data analysis, modeling, and simulation. This article provides a comprehensive investigation into cubic spline interpolation MATLAB, exploring its mathematical foundations, implementation strategies, practical considerations, and applications.

Understanding Cubic Spline Interpolation

Mathematical Foundations

Cubic spline interpolation constructs a piecewise function composed of cubic polynomials between each pair of data points. Given a set of data points $((x_0, y_0), (x_1, y_1), \dots, (x_n, y_n))$, the goal is to find a function $S(x)$ such that:

- $S(x)$ interpolates the data points: $S(x_i) = y_i$ for all i .
- $S(x)$ is continuous and has continuous first and second derivatives over the entire interval $[x_0, x_n]$.

Formally, for each subinterval $[x_i, x_{i+1}]$, the interpolant $S_i(x)$ is a cubic polynomial:

$$S_i(x) = a_i + b_i (x - x_i) + c_i (x - x_i)^2 + d_i (x - x_i)^3$$

The coefficients $\{a_i, b_i, c_i, d_i\}$ are determined by solving a system of equations derived from the interpolation conditions and smoothness requirements.

Key Properties:

- Continuity: $S(x)$ is continuous across the entire domain.
- Smoothness: The first and second derivatives are continuous, ensuring a smooth curve without abrupt changes.
- Local Control: Modifying one data point affects only neighboring spline segments.

Advantages over Other Interpolations

Compared to polynomial interpolation of high degree, cubic splines are less prone to Runge's phenomenon (oscillations at the edges). They provide a more natural and visually appealing fit, particularly for data with smooth underlying trends.

Implementation of Cubic Spline Interpolation in MATLAB

Built-in Functions and Toolboxes

MATLAB offers robust, built-in functionality for cubic spline interpolation, notably through the `spline()` and `csape()` functions in the Curve Fitting Toolbox. These functions simplify the process, allowing users to generate spline interpolants with minimal code.

Common Functions:

- `spline(x, y, xx)`: Computes the cubic spline interpolation of data points and evaluates it at specified points `xx`.
- `interp1(x, y, xx, 'spline')`: Performs 1-D interpolation using the spline method.
- `csape(x, y, 'variational')`: Creates a cubic spline with specified boundary conditions.

Example:

```
```matlab
x = [0, 1, 2, 3, 4];
y = [0, 1, 0, 1, 0];
xx = linspace(0, 4, 100);
```

```
yy = spline(x, y, xx);

plot(x, y, 'o', xx, yy, '-');
title('Cubic Spline Interpolation in MATLAB');
xlabel('x');
ylabel('Interpolated y');
legend('Data Points', 'Spline Curve');
```

```

This example illustrates how simple it is to generate a smooth cubic spline curve fitting the data points.

Implementation from Scratch

For educational or customized purposes, implementing cubic spline interpolation manually involves solving a tridiagonal system to compute the spline coefficients.

Step-by-step process:

1. Compute interval sizes $(h_i = x_{i+1} - x_i)$.
2. Set up the system for second derivatives (M_i) , often called the "natural spline" conditions where $(M_0 = M_n = 0)$.
3. Solve the tridiagonal system:

$$\begin{bmatrix} 2(h_0 + h_1) & h_1 & & \\ h_1 & 2(h_1 + h_2) & h_2 & \\ & \ddots & \ddots & \ddots \\ & & h_{n-1} & 2(h_{n-1} + h_n) \end{bmatrix} \begin{bmatrix} M_0 \\ M_1 \\ \vdots \\ M_n \end{bmatrix} = \begin{bmatrix} 3 \frac{(y_1 - y_0)}{h_0} - 3 \frac{(y_0 - y_{-1})}{h_{-1}} \\ \vdots \\ 3 \frac{(y_n - y_{n-1})}{h_{n-1}} - 3 \frac{(y_{n-1} - y_{n-2})}{h_{n-2}} \end{bmatrix}$$

4. Calculate spline coefficients (a_i, b_i, c_i, d_i) .
5. Evaluate the spline at desired points using the coefficients.

This manual approach provides insight into the underlying mathematics and offers flexibility for

boundary conditions.

Practical Considerations and Challenges

Choice of Boundary Conditions

Depending on the problem, boundary conditions influence the shape of the spline at the endpoints. Common options include:

- Natural spline: Second derivatives at endpoints are zero ($M_0 = M_n = 0$).
- Clamped spline: Derivatives at endpoints are specified.
- Not-a-knot spline: Higher smoothness at internal knots, reducing endpoint constraints.

MATLAB's `spline()` function defaults to natural boundary conditions, but users can specify others using functions like `csape()`.

Handling Irregular Data

Data with uneven spacing or noise poses challenges:

- Uneven data: Cubic splines adapt well, but care must be taken to avoid overfitting.
- Noisy data: Smoothing splines or regularization methods may be more appropriate to prevent oscillations.

Computational Stability and Efficiency

In large datasets, solving large systems can be computationally intensive. Efficient algorithms, such as Thomas' algorithm for tridiagonal matrices, ensure stability and speed.

Applications of Cubic Spline Interpolation in MATLAB

Engineering and Scientific Data Modeling

- Signal Processing: Smoothing and reconstructing signals.
- Control Systems: Designing smooth control functions.

- Structural Analysis: Modeling stress-strain curves.

Image Processing and Computer Graphics

- Generating smooth curves and contours.
- Morphing and animation paths.

Data Visualization and Analysis

- Creating polished plots that interpolate data points smoothly.
- Estimating derivatives for further analysis.

Case Study: Experimental Data Fitting

Suppose an experiment yields temperature measurements at various time points. Using cubic spline interpolation in MATLAB, researchers can:

- Generate a smooth temperature-time curve.
- Calculate derivatives to find rates of change.
- Interpolate data at unmeasured points for better resolution.

Conclusion and Future Directions

Cubic spline interpolation MATLAB embodies a cornerstone of numerical analysis, combining mathematical rigor with practical implementation. Its ability to generate smooth, accurate interpolants makes it indispensable across scientific disciplines. MATLAB's comprehensive functions, coupled with the option to implement custom algorithms, provide users with flexible tools tailored to their specific needs.

Advancements in computational methods continue to enhance spline techniques, including adaptive spline methods, multivariate splines, and spline-based machine learning models. As data complexity grows, so does the importance of efficient, robust interpolation strategies like cubic splines.

In summary, mastery of cubic spline interpolation MATLAB not only facilitates precise data modeling but also deepens understanding of underlying mathematical principles, ultimately empowering researchers and engineers to make informed decisions grounded in accurate data representation.

References:

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Note: For implementation details, MATLAB code snippets, and further case studies, consult MATLAB's official documentation and supplemental tutorials on spline interpolation techniques.

Cubic Spline Interpolation Matlab

cubic spline interpolation matlab: Spline Fitting With Matlab J. Braselton, 2014-09-10 Curve Fitting Toolbox provides graphical tools and command-line functions for fitting curves and surfaces to data. The toolbox lets you perform exploratory data analysis, preprocess and post-process data, compare candidate models, and remove outliers. You can conduct regression analysis using the library of linear and nonlinear models provided or specify your own custom equations. The library provides optimized solver parameters and starting conditions to improve the quality of your fits. The toolbox also supports nonparametric modeling techniques, such as splines, interpolation, and smoothing. After creating a fit, you can apply a variety of post-processing methods for plotting, interpolation, and extrapolation; estimating confidence intervals; and calculating integrals and derivatives. The most important topics in this book are: Interactive Spline Fitting Programmatic Spline Fitting Curve Fitting Toolbox Splines MATLAB Splines Expected Background Vector Data Type Support Spline Function Naming Conventions Arguments for Curve Fitting Toolbox Spline Functions Cubic Spline Interpolation Cubic Spline Interpolant of Smooth Data Periodic Data Other End Conditions General Spline Interpolation Knot Choices Smoothing Least Squares Vector-Valued Functions Fitting Values at N-D Grid with Tensor-Product Splines Fitting Values at Scattered 2-D Sites with Thin-Plate Smoothing Splines Postprocessing Splines B-Splines and Smoothing Splines Multivariate and Rational Splines Least-Squares Approximation by Natural Cubic Splines Solving A Nonlinear ODE Construction of the Chebyshev Spline Approximation by Tensor Product Splines

cubic spline interpolation matlab: CURVE and SURFACE FITTING with MATLAB. INTERPOLATION, SMOOTHING and SPLINE FITTING A Ramirez, 2019-07-24 The Curve Fitting Toolbox software supports these nonparametric fitting methods: -Interpolation Methods - Estimate values that lie between known data points.-Smoothing Splines - Create a smooth curve through the data. You adjust the level of smoothness by varying a parameter that changes the curve from a least-squares straight-line approximation to a cubic spline interpolant.-Lowess Smoothing - Create a smooth surface through the data using locally weighted linear regression to smooth data. Interpolation is a process for estimating values that lie between known data points. There are several interpolation methods: - Linear: Linear interpolation. This method fit a different linear polynomial between each pair of data points for curves, or between sets of three points for surfaces.- Nearest neighbor: Nearest neighbor interpolation. This method sets the value of an interpolated point to the value of the nearest data point. Therefore, this method does not generate any new data points.- Cubic spline: Cubic spline interpolation. This method fit a different cubic polynomial between each pair of data points for curves, or between sets of three points for surfaces. After fitting data with one or more models, you should evaluate the goodness of fit A visual examination of the fitted curve displayed in Curve Fitting app should be your first step. Beyond that, the toolbox provides these methods to assess goodness of fit for both linear and nonlinear parametric fits-Goodness-of-Fit

Statistics -Residual Analysis -Confidence and Prediction Bounds The Curve Fitting Toolbox spline functions are a collection of tools for creating, viewing, and analyzing spline approximations of data. Splines are smooth piecewise polynomials that can be used to represent functions over large intervals, where it would be impractical to use a single approximating polynomial. The spline functionality includes a graphical user interface (GUI) that provides easy access to functions for creating, visualizing, and manipulating splines. The toolbox also contains functions that enable you to evaluate, plot, combine, differentiate and integrate splines. Because all toolbox functions are implemented in the open MATLAB language, you can inspect the algorithms, modify the source code, and create your own custom functions. Key spline features: -GUIs that let you create, view, and manipulate splines and manage and compare spline approximations-Functions for advanced spline operations, including differentiation integration, break/knot manipulation, and optimal knot placement-Support for piecewise polynomial form (ppform) and basis form (B-form) splines-Support for tensor-product splines and rational splines (including NURBS)- Shape-preserving: Piecewise cubic Hermite interpolation (PCHIP). This method preserves monotonicity and the shape of the data. For curves only.- Biharmonic (v4): MATLAB 4 grid data method. For surfaces only.- Thin-plate spline: Thin-plate spline interpolation. This method fit smooth surfaces that also extrapolate well. For surfaces only.If your data is noisy, you might want to fit it using a smoothing spline. Alternatively, you can use one of the smoothing methods. The smoothing spline s is constructed for the specified smoothing parameter p and the specified weights w_i .

cubic spline interpolation matlab: Process Modelling and Simulation with Finite Element Methods William B. J. Zimmerman, 2004 This book presents a systematic description and case studies of chemical engineering modelling and simulation based on the MATLAB/FEMLAB tools, in support of selected topics in undergraduate and postgraduate programmes that require numerical solution of complex balance equations (ordinary differential equations, partial differential equations, nonlinear equations, integro-differential equations). These systems arise naturally in analysis of transport phenomena, process systems, chemical reactions and chemical thermodynamics, and particle rate processes. Templates are given for modelling both state-of-the-art research topics (e.g. microfluidic networks, film drying, multiphase flow, population balance equations) and case studies of commonplace design calculations -- mixed phase reactor design, heat transfer, flowsheet analysis of unit operations, flash distillations, etc. The great strength of this book is that it makes modelling and simulating in the MATLAB/FEMLAB environment approachable to both the novice and the expert modeller.

cubic spline interpolation matlab: Handbook of Marine Craft Hydrodynamics and Motion Control Thor I. Fossen, 2021-03-22 Handbook of MARINE CRAFT HYDRODYNAMICS AND MOTION CONTROL The latest tools for analysis and design of advanced GNC systems Handbook of Marine Craft Hydrodynamics and Motion Control is an extensive study of the latest research in hydrodynamics, guidance, navigation, and control systems for marine craft. The text establishes how the implementation of mathematical models and modern control theory can be used for simulation and verification of control systems, decision-support systems, and situational awareness systems. Coverage includes hydrodynamic models for marine craft, models for wind, waves and ocean currents, dynamics and stability of marine craft, advanced guidance principles, sensor fusion, and inertial navigation. This important book includes the latest tools for analysis and design of advanced GNC systems and presents new material on unmanned underwater vehicles, surface craft, and autonomous vehicles. References and examples are included to enable engineers to analyze existing projects before making their own designs, as well as MATLAB scripts for hands-on software development and testing. Highlights of this Second Edition include: Topical case studies and worked examples demonstrating how you can apply modeling and control design techniques to your own designs A Github repository with MATLAB scripts (MSS toolbox) compatible with the latest software releases from Mathworks New content on mathematical modeling, including models for ships and underwater vehicles, hydrostatics, and control forces and moments New methods for guidance and navigation, including line-of-sight (LOS) guidance laws for path following, sensory systems,

model-based navigation systems, and inertial navigation systems This fully revised Second Edition includes innovative research in hydrodynamics and GNC systems for marine craft, from ships to autonomous vehicles operating on the surface and under water. Handbook of Marine Craft Hydrodynamics and Motion Control is a must-have for students and engineers working with unmanned systems, field robots, autonomous vehicles, and ships. MSS toolbox:

<https://github.com/cybergalactic/mss> Lecture notes: <https://www.fossen.biz/wiley> Author's home page: <https://www.fossen.biz>

cubic spline interpolation matlab: Basic Principles and Calculations in Chemical Engineering David M. Himmelblau, James B. Riggs, 2022-07-27 The #1 Guide to Chemical Engineering Principles, Techniques, Calculations, and Applications--Revised, Streamlined, and Modernized with New Examples Basic Principles and Calculations in Chemical Engineering, Ninth Edition, has been thoroughly revised, streamlined, and updated to reflect sweeping changes in the chemical engineering field. This introductory guide addresses the full scope of contemporary chemical, petroleum, and environmental engineering applications and contains extensive new coverage and examples related to biotech, nanotech, green/environmental engineering, and process safety, with many new MATLAB and Python problems throughout. Authors David M. Himmelblau and James B. Riggs offer a strong foundation of skills and knowledge for successful study and practice, guiding students through formulating and solving material and energy balance problems, as well as describing gases, liquids, and vapors. Throughout, they introduce efficient, consistent, learner-friendly ways to solve problems, analyze data, and gain a conceptual, application-based understanding of modern processes. This edition condenses coverage from previous editions to serve today's students and faculty more efficiently. In two entirely new chapters, the authors provide a comprehensive introduction to dynamic material and energy balances, as well as psychrometric charts. Modular chapters designed to support introductory courses of any length Introductions to unit conversions, basis selection, and process measurements Strategies for solving diverse material and energy balance problems, including material balances with chemical reaction and for multi-unit processes, and energy balances with reaction Clear introductions to key concepts ranging from stoichiometry to enthalpy Coverage of ideal/real gases, multi-phase equilibria, unsteady-state material, humidity (psychrometric) charts, and more Self-assessment questions to help readers identify areas they don't fully understand Thought, discussion, and homework problems in every chapter New biotech, bioengineering, nanotechnology, green/environmental engineering, and process safety coverage Relevant new MATLAB and Python homework problems and projects Extensive tables, charts, and glossaries in each chapter Reference appendices presenting atomic weights and numbers, Pitzer Z^0/Z^1 factors, heats of formation and combustion, and more Easier than ever to use, this book is the definitive practical introduction for students, license candidates, practicing engineers, and scientists. Supplemental Online Content (available with book registration): Three additional chapters on Heats of Solution and Mixing, Liquids and Gases in Equilibrium with Solids, and Solving Material and Energy Balances with Process Simulators (Flowsheeting Codes) Nine additional appendices: Physical Properties of Various Organic and Inorganic Substances, Heat Capacity Equations, Vapor Pressures, Heats of Solution and Dilution, Enthalpy-Concentration Data, Thermodynamic Charts, Physical Properties of Petroleum Fractions, Solution of Sets of Equations, Fitting Functions to Data Register your book for convenient access to downloads, updates, and/or corrections as they become available. See inside book for details.

cubic spline interpolation matlab: *Image Super-Resolution and Applications* Fathi E. Abd El-Samie, Mohiy M. Hadhoud, Said E. El-Khamy, 2012-12-15 This book is devoted to the issue of image super-resolution—obtaining high-resolution images from single or multiple low-resolution images. Although there are numerous algorithms available for image interpolation and super-resolution, there's been a need for a book that establishes a common thread between the two processes. Filling this need, Image Super-Resolution and Applications presents image interpolation as a building block in the super-resolution reconstruction process. Instead of approaching image interpolation as either a polynomial-based problem or an inverse problem, this book breaks the mold

and compares and contrasts the two approaches. It presents two directions for image super-resolution: super-resolution with a priori information and blind super-resolution reconstruction of images. It also devotes chapters to the two complementary steps used to obtain high-resolution images: image registration and image fusion. Details techniques for color image interpolation and interpolation for pattern recognition Analyzes image interpolation as an inverse problem Presents image registration methodologies Considers image fusion and its application in image super resolution Includes simulation experiments along with the required MATLAB® code Supplying complete coverage of image-super resolution and its applications, the book illustrates applications for image interpolation and super-resolution in medical and satellite image processing. It uses MATLAB® programs to present various techniques, including polynomial image interpolation and adaptive polynomial image interpolation. MATLAB codes for most of the simulation experiments supplied in the book are included in the appendix.

cubic spline interpolation matlab: Applied Numerical Methods for Chemical Engineers

Navid Mostoufi, Alkis Constantinides, 2022-05-22 Applied Numerical Methods for Chemical Engineers emphasizes the derivation of a variety of numerical methods and their application to the solution of engineering problems, with special attention to problems in the chemical engineering field. These algorithms encompass linear and nonlinear algebraic equations, eigenvalue problems, finite difference methods, interpolation, differentiation and integration, ordinary differential equations, boundary value problems, partial differential equations, and linear and nonlinear regression analysis. MATLAB is adopted as the calculation environment throughout the book because of its ability to perform all the calculations in matrix form, its large library of built-in functions, its strong structural language, and its rich graphical visualization tools. Through this book, students and other users will learn about the basic features, advantages and disadvantages of various numerical methods, learn and practice many useful m-files developed for different numerical methods in addition to the MATLAB built-in solvers, develop and set up mathematical models for problems commonly encountered in chemical engineering, and solve chemical engineering related problems through examples and after-chapter problems with MATLAB by creating application m-files. - Clearly and concisely develops a variety of numerical methods and applies them to the solution of chemical engineering problems. These algorithms encompass linear and nonlinear algebraic equations, eigenvalue problems, finite difference methods, interpolation, linear and nonlinear regression analysis, differentiation and integration, ordinary differential equations, boundary value problems, and partial differential equations - Includes systematic development of the calculus of finite differences and its application to the integration of differential equations, and a detailed discussion of nonlinear regression analysis, with powerful programs for implementing multivariable nonlinear regression and statistical analysis of the results - Makes extensive use of MATLAB and Excel, with most of the methods discussed implemented into general MATLAB functions. All the MATLAB-language scripts developed are listed in the text and included in the book's companion website - Includes numerous real-world examples and homework problems drawn from the field of chemical and biochemical engineering

cubic spline interpolation matlab: Guide to Scientific Computing Peter R. Turner, 2001 This book introduces the reader to many of the problems of scientific computing and the wide variety of methods used for their solutions. It discusses basic approaches and stimulates an appreciation of the need for numerical methods in solving different types of problems. For each of the problems presented, the author provides some mathematical justification and examples. These serve as practical evidence and motivation for the reader to follow. Practical justification of the methods is provided through computer examples and exercises. The book includes an introduction to MATLAB, but the code used is not intended to exemplify sophisticated or robust pieces of software; it is purely illustrative of the method under discussion.

cubic spline interpolation matlab: Applications of Computational Intelligence Alvaro

David Orjuela-Cañón, Jesus A Lopez, Julián David Arias-Londoño, 2023-11-17 This book constitutes the refereed proceedings of the 6th IEEE Colombian Conference on Applications of Computational

Intelligence, ColCACI 2023, held in Bogota, Colombia during July 2023. A total of 11 full papers were carefully reviewed and selected from 42 submissions. They were organized in topical sections as follows: Biomedical Applications, Biological Applications, Engineering Applications.

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