NUMERICAL METHODS

LEAST SQUARES SCORE (RMS)

(GOAL: MINIMIZE THE SUM OF THE SQUARE OF THE RESIDUAL ERRORS)

$$S_r = \sum e_i^2 = \sum (z_i - a_0 - a_1 x_i)^2$$

$$a_1 = \frac{n\sum(x_i y_i) - \sum x_i \sum y_i}{n\sum(x_i^2) - (\sum x_i)^2}$$

$$a_0 = \frac{\sum y_i}{n}, \quad a_1 = \frac{\sum x_i}{n} \Rightarrow a_0 = \bar{y} - a_1 \bar{x}$$

MEAN:
$$a_0 = \bar{y} - a_1 \bar{x}$$
$$y = a_0 + a_1 x$$

POLYNOMIAL (QUADRATIC) REGRESSION:

$$S_r = \sum (y_i - a_0 - a_1 x_i - a_2 x_i^2)^2$$

(TAKE DERIVATIVE OF S_r TO FIND THE MINIMUM ERROR)

$$\frac{\partial S_r}{\partial a_0} = -2(\sum y_i - \sum a_0 - a_1 \sum x_i - a_2 \sum x_i^2) = 0$$

$$\frac{\partial S_r}{\partial a_1} = -2(\sum y_i x_i - \sum a_0 x_i - a_1 \sum x_i^2 - a_2 \sum x_i^3) = 0$$

$$\frac{\partial S_r}{\partial a_2} = -2(\sum y_i x_i^2 - \sum a_0 x_i^2 - a_1 \sum x_i^3 - a_2 \sum x_i^4) = 0$$

$$\sum a_0 = a_0 n$$

$$[A][X] = [B]$$

$$X = A \backslash B$$

COEFFICIENT OF DETERMINATION:
$$r^2 = \frac{S_t - S_r}{S_t}$$

STANDARD ERROR:

$$S_y = \sqrt{\frac{S_r}{n-2}} \qquad S_{y/x} = \sqrt{\frac{\sum(z_i - y_i^{(i)})^2}{n-2}}$$

STAND DEVIATION:

$$S_y = \sqrt{\frac{S_t}{n-1}} \qquad S_y = \sqrt{\frac{\sum(y_i - \bar{y})^2}{n-1}}$$

INTERPOLATION
- USE A POLYNOMIAL FIT:

$$P_n(x) = a_0 + a_1 x + a_2 x^2 + \cdots + a_n x^n$$

ORDER / TURNS

n	
n = 1	0
n = 2	1
n = 3	2
n = 4	3
n = n	n-1

SPLINES:
$$m_i = \frac{f(x_{i+1}) - f(x_i)}{x_{i+1} - x_i}$$

ODE'S
- EULER'S METHOD:
$$\frac{dy}{dx} = f(x,y)$$
$$y_{i+1} = y_i + f(x_i, y_i)h$$

- HEUN'S METHOD:
$$\frac{dy}{dx} = f(x,y)$$
$$\frac{dy_i}{dx} = y_i' = f(x_i, y_i)$$
$$y' = \frac{y_i' + y_{i+1}'}{2} = \frac{f(x_i, y_i) + f(x_{i+1}, y_{i+1}^0)}{2}$$
$$y_{i+1} = y_i + \frac{f(x_i, y_i) + f(x_{i+1}, y_{i+1}^0)}{2}\Delta x$$

- TAYLOR SERIES:
$$y(x + \Delta x) = y(x) + \frac{dy}{dx}(x_0)\Delta x$$
$$y(x + \Delta x) = y(x) + f(x,y)\Delta x$$

CLASSIC 4TH ORDER RUNGE-KUTTA:
$$y_{i+1} = y_i + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)\Delta x$$
$$k_1 = f(x_i, y_i)$$
$$k_2 = f(x_i + \tfrac{1}{2}\Delta x, \; y_i + \tfrac{1}{2}k_1 \Delta x)$$
$$k_3 = f(x_i + \tfrac{1}{2}\Delta x, \; y_i + \tfrac{1}{2}k_2 \Delta x)$$
$$k_4 = f(x_i + \Delta x, \; y_i + k_3 \Delta x)$$

DORMAND-PRINCE RUNGE-KUTTA

EIGEN VALUES
λ = EIGEN VALUE

SIMPLE 2x2:
$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$$
$$[X] = \frac{1}{\det(A)}\begin{bmatrix} d & -b \\ -c & a \end{bmatrix}[B]$$
$$\lambda = \frac{(a+d) \pm \sqrt{(a+d)^2 - 4(ad - bc)}}{2}$$

PDE'S

FINITE DIFFERENCE METHOD:

TEMPERATURE

BC:
- TEMP KNOWN @ BOUNDARY

GOVERNING HEAT EQN:
$$u_t = k(u_{xx} + u_{yy}) + q$$

- CENTRAL DIFFERENCE
$$u_{xx}(x,y) = \frac{u(x - \Delta x, y) - 2u(x,y) + u(x + \Delta x, y)}{\Delta x^2}$$
$$u_{yy}(x,y) = \frac{u(x, y - \Delta y) - 2u(x,y) + u(x, y + \Delta y)}{\Delta y^2}$$

NEUMANN:
BC:
- TEMP DERIVATIVE KNOWN ON BOUNDARY

CENTRAL DIFFERENCE:
$$\frac{\partial u}{\partial x} = q_x = \frac{u_{i+1,j} - u_{i-1,j}}{2\Delta x}$$
$$\frac{\partial u}{\partial y} = q_y = \frac{u_{i,j+1} - u_{i,j-1}}{2\Delta y}$$

RIGHT NEUMANN B.C.
$$\frac{\partial u}{\partial x} = q_x = \frac{u_{i+1,j} - u_{i-1,j}}{2\Delta x}$$
$$u_{i+1,j} = u_{i-1,j} + 2\Delta x q_x$$

BOTTOM NEUMANN B.C.
$$\frac{\partial u}{\partial y} = q_y = \frac{u_{i,j+1} - u_{i,j-1}}{2\Delta y}$$
$$u_{i,j-1} = u_{i,j+1} - 2\Delta y q_y$$

TOP NEUMANN B.C.
$$\frac{\partial u}{\partial y} = q_y = \frac{u_{i,j+1} - u_{i,j-1}}{2\Delta y}$$
$$u_{i,j+1} = u_{i,j-1} + 2\Delta y q_y$$

LEFT NEUMANN B.C.
$$u_{i-1,j} = u_{i+1,j} - 2\Delta x q_x$$

[A] MATRIX:
LEFT:
$$u_{i-1,j} + 4u_{i,j} - u_{i,j+1} - u_{i,j-1} = 2\Delta x q_x$$
$$-2u_{i+1,j} + 4u_{i,j} - u_{i,j+1} - u_{i,j-1} = -2\Delta x q_x$$
RIGHT:
$$-2u_{i-1,j} + 4u_{i,j} - u_{i,j+1} - u_{i,j-1} = -2\Delta x q_x$$
BOTTOM:
$$-u_{i-1,j} - u_{i+1,j} + 4u_{i,j} - 2u_{i,j+1} = -2\Delta y q_y$$
TOP:
$$-u_{i-1,j} - u_{i+1,j} + 4u_{i,j} - 2u_{i,j-1} = -2\Delta y q_y$$

MISC EQN'S:
CENTERED FINITE DIVIDED DIFFERENCE:
$$f'(x_i) = \frac{f(x_{i+1}) - f(x_{i-1})}{2h}$$
$$f'(x_i) = \frac{-f(x_{i+2}) + 8f(x_{i+1}) - 8f(x_{i-1}) + f(x_{i-2})}{12h}$$

Methods Of Numerical Mathematics

Chris Woodford,C. Woodford,Chris Phillips

Methods Of Numerical Mathematics:

   Methods of Numerical Mathematics G.I. Marchuk,1982-05-11 The present volume is an adaptation of a series of lectures on numerical mathematics which the author has been giving to students of mathematics at the Novosibirsk State University during the span of several years In dealing with problems of applied and numerical mathematics the author sought to focus his attention on those complicated problems of mathe matical physics which in the course of their solution can be reduced to simpler and theoretically better developed problems allowing effective algorithmic realization on modern computers It is usually these kinds of problems that a young practicing scientist runs into after finishing his university studies Therefore this book is pri marily intended for the benefit of those encountering truly complicated problems of mathematical physics for the first time who may seek help regarding rational approaches to their solution In writing this book the author has also tried to take into account the needs of scientists and engineers who already have a solid background in practical problems but who lack a systematic knowledge in areas of numerical mathematics and its more general theoretical framework   An Introduction to Numerical Methods and Analysis James F. Epperson,2007-09-17 Praise for the First Edition outstandingly appealing with regard to its style contents considerations of requirements of practice choice of examples and exercises Zentrablatt Math carefully structured with many detailed worked examples The Mathematical Gazette an up to date and user friendly account Mathematika An Introduction to Numerical Methods and Analysis addresses the mathematics underlying approximation and scientific computing and successfully explains where approximation methods come from why they sometimes work or don t work and when to use one of the many techniques that are available Written in a style that emphasizes readability and usefulness for the numerical methods novice the book begins with basic elementary material and gradually builds up to more advanced topics A selection of concepts required for the study of computational mathematics is introduced and simple approximations using Taylor s Theorem are also treated in some depth The text includes exercises that run the gamut from simple hand computations to challenging derivations and minor proofs to programming exercises A greater emphasis on applied exercises as well as the cause and effect associated with numerical mathematics is featured throughout the book An Introduction to Numerical Methods and Analysis is the ideal text for students in advanced undergraduate mathematics and engineering courses who are interested in gaining an understanding of numerical methods and numerical analysis   **Methods of Numerical Mathematics** G.I. Marchuk,1976-01-02

   Methods of Numerical Mathematics Gurij Ivanovič Marčuk,1975   **Numerical Methods in Economics** Kenneth L. Judd,1998-09-28 To harness the full power of computer technology economists need to use a broad range of mathematical techniques In this book Kenneth Judd presents techniques from the numerical analysis and applied mathematics literatures and shows how to use them in economic analyses The book is divided into five parts Part I provides a general introduction Part II presents basics from numerical analysis on R n including linear equations iterative methods optimization nonlinear

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fifth edition continues to provide a rigorous introduction to the fundamentals of numerical methods required in scientific and technological applications emphasizing on teaching students numerical methods and in helping them to develop problem solving skills While the essential features of the previous editions such as References to MATLAB IMSL Numerical Recipes program libraries for implementing the numerical methods are retained a chapter on Spline Functions has been added in this edition because of their increasing importance in applications This text is designed for undergraduate students of all branches of engineering NEW TO THIS EDITION Includes additional modified illustrative examples and problems in every chapter Provides answers to all chapter end exercises Illustrates algorithms computational steps or flow charts for many numerical methods Contains four model question papers at the end of the text *Fundamentals of Numerical Mathematics for Physicists and Engineers* Alvaro Meseguer,2020-05-26 Introduces the fundamentals of numerical mathematics and illustrates its applications to a wide variety of disciplines in physics and engineering Applying numerical mathematics to solve scientific problems this book helps readers understand the mathematical and algorithmic elements that lie beneath numerical and computational methodologies in order to determine the suitability of certain techniques for solving a given problem It also contains examples related to problems arising in classical mechanics thermodynamics electricity and quantum physics Fundamentals of Numerical Mathematics for Physicists and Engineers is presented in two parts Part I addresses the root finding of univariate transcendental equations polynomial interpolation numerical differentiation and numerical integration Part II examines slightly more advanced topics such as introductory numerical linear algebra parameter dependent systems of nonlinear equations numerical Fourier analysis and ordinary differential equations initial value problems and univariate boundary value problems Chapters cover Newton s method Lebesgue constants conditioning barycentric interpolatory formula Clenshaw Curtis quadrature GMRES matrix free Krylov linear solvers homotopy numerical continuation differentiation matrices for boundary value problems Runge Kutta and linear multistep formulas for initial value problems Each section concludes with Matlab hands on computer practicals and problem and exercise sets This book Provides a modern perspective of numerical mathematics by introducing top notch techniques currently used by numerical analysts Contains two parts each of which has been designed as a one semester course Includes computational practicals in Matlab with solutions at the end of each section for the instructor to monitor the student s progress through potential exams or short projects Contains problem and exercise sets also with solutions at the end of each section Fundamentals of Numerical Mathematics for Physicists and Engineers is an excellent book for advanced undergraduate or graduate students in physics mathematics or engineering It will also benefit students in other scientific fields in which numerical methods may be required such as chemistry or biology   **Concise Numerical Mathematics** Robert Plato,2003 This book succinctly covers the key topics of numerical methods While it is basically a survey of the subject it has enough depth for the student to walk away with the ability to implement the methods by writing computer programs or by applying them to problems in

physics or engineering The author manages to cover the essentials while avoiding redundancies and using well chosen examples and exercises The exposition is supplemented by numerous figures Work estimates and pseudo codes are provided for many algorithms which can be easily converted to computer programs Topics covered include interpolation the fast Fourier transform iterative methods for solving systems of linear and nonlinear equations numerical methods for solving ODEs numerical methods for matrix eigenvalue problems approximation theory and computer arithmetic In general the author assumes only a knowledge of calculus and linear algebra The book is suitable as a text for a first course in numerical methods for mathematics students or students in neighboring fields such as engineering physics and computer science

   Numerical Methods that Work Forman S. Acton,1990 A commonsense approach to numerical algorithms for the solution of equations   Numerical Methods for Differential Equations J.R. Dormand,2018-05-04 With emphasis on modern techniques Numerical Methods for Differential Equations A Computational Approach covers the development and application of methods for the numerical solution of ordinary differential equations Some of the methods are extended to cover partial differential equations All techniques covered in the text are on a program disk included with the book and are written in Fortran 90 These programs are ideal for students researchers and practitioners because they allow for straightforward application of the numerical methods described in the text The code is easily modified to solve new systems of equations Numerical Methods for Differential Equations A Computational Approach also contains a reliable and inexpensive global error code for those interested in global error estimation This is a valuable text for students who will find the derivations of the numerical methods extremely helpful and the programs themselves easy to use It is also an excellent reference and source of software for researchers and practitioners who need computer solutions to differential equations   *Introduction to Numerical Analysis and Scientific Computing* Nabil Nassif,Dolly Khuwayri Fayyad,2016-04-19 Designed for a one semester course Introduction to Numerical Analysis and Scientific Computing presents fundamental concepts of numerical mathematics and explains how to implement and program numerical methods The classroom tested text helps students understand floating point number representations particularly those pertaining to IEEE simple an   *Numerical Methods for Ordinary Differential Equations* David F. Griffiths,Desmond J. Higham,2010-11-11 Numerical Methods for Ordinary Differential Equations is a self contained introduction to a fundamental field of numerical analysis and scientific computation Written for undergraduate students with a mathematical background this book focuses on the analysis of numerical methods without losing sight of the practical nature of the subject It covers the topics traditionally treated in a first course but also highlights new and emerging themes Chapters are broken down into lecture sized pieces motivated and illustrated by numerous theoretical and computational examples Over 200 exercises are provided and these are starred according to their degree of difficulty Solutions to all exercises are available to authorized instructors The book covers key foundation topics o Taylor series methods o Runge Kutta methods o Linear multistep methods o Convergence o Stability and a range of modern

themes o Adaptive stepsize selection o Long term dynamics o Modified equations o Geometric integration o Stochastic differential equations The prerequisite of a basic university level calculus class is assumed although appropriate background results are also summarized in appendices A dedicated website for the book containing extra information can be found via www springer com   *Numerical Methods in Multibody Dynamics* Claus Führer,2013-11-11 Numerical Analysis is an interdisciplinary topic which develops its strength only when viewed in close connection with applications Nowadays mechanical engineers having computer simulation as a daily engineering tool have to learn more and more techniques from that field Mathematicians on the other hand are increasingly confronted with the need for developing special purpose methods and codes This requires a broad interdisciplinary understanding and a sense for model method interactions With this monograph we give an introduction to selected topics of Numerical Anal ysis based on these facts We dedicate our presentations to an interesting discipline in computational engineering multibody dynamics Though the basic ideas and methods apply to other engineering fields too we emphasize on having one homo geneous class of applications Both authors worked through many years in teams developing multibody codes Interdisciplinary work also includes transferring ideas from one field to the other and a big amount of teaching and that was the idea of this book This book is intended for students of mathematics engineering and computer sci ence as well as for people already concerned with the solution of related topics in university and industry After a short introduction to multibody systems and the mathematical formulation of the equations of motion different numerical methods used to solve simulation tasks are presented The presentation is supported by a simple model of a truck This truck model will follow the reader from the title page to the appendix in various versions specially adapted to the topics

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Table of Contents Methods Of Numerical Mathematics

1. Understanding the eBook Methods Of Numerical Mathematics
    - The Rise of Digital Reading Methods Of Numerical Mathematics
    - Advantages of eBooks Over Traditional Books
2. Identifying Methods Of Numerical Mathematics
    - Exploring Different Genres
    - Considering Fiction vs. Non-Fiction
    - Determining Your Reading Goals
3. Choosing the Right eBook Platform
    - Popular eBook Platforms
    - Features to Look for in an Methods Of Numerical Mathematics
    - User-Friendly Interface
4. Exploring eBook Recommendations from Methods Of Numerical Mathematics
    - Personalized Recommendations
    - Methods Of Numerical Mathematics User Reviews and Ratings
    - Methods Of Numerical Mathematics and Bestseller Lists
5. Accessing Methods Of Numerical Mathematics Free and Paid eBooks
    - Methods Of Numerical Mathematics Public Domain eBooks

14. Embracing eBook Trends
    - Integration of Multimedia Elements
    - Interactive and Gamified eBooks

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