

# NUMERICAL METHODS

C / RAPPY EXAM 12 / 11/19 / 2022 [20.000]

## LEAST SQUARES REGRESSION

GOAL: MINIMIZE THE SUM OF THE SQUARES OF THE RESIDUALS (ERRORS)

RESIDUAL:  $r_i = y_i - \hat{y}_i$

MINIMIZE:  $S = \sum_{i=1}^n r_i^2 = \sum_{i=1}^n (y_i - a_0 - a_1 x_i)^2$

COEFFICIENTS:  $a_0 = \frac{\sum y_i - a_1 \sum x_i}{n}$

COEFFICIENTS:  $a_0 = \frac{\sum y_i}{n} - a_1 \frac{\sum x_i}{n}$

## POLYNOMIAL QUADRATIC REGRESSION:



$S = \sum_{i=1}^n (y_i - a_0 - a_1 x_i - a_2 x_i^2)^2$

TAKE DERIVATIVE OF S TO FIND MINIMUM

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

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

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

$\begin{bmatrix} \sum 1 & \sum x_i & \sum x_i^2 \\ \sum x_i & \sum x_i^2 & \sum x_i^3 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum x_i y_i \\ \sum x_i^2 y_i \end{bmatrix}$

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

$X = A^{-1}B$

## STANDARD ERROR:

$S_y = \sqrt{\frac{\sum y_i^2}{n-2}}$      $S_{y-x} = \sqrt{\frac{\sum (y_i - \hat{y}_i)^2}{n-2}}$

## STANDARD DEVIATION:

$S_y = \sqrt{\frac{\sum y_i^2}{n-1}}$      $S_{y-x} = \sqrt{\frac{\sum (y_i - \hat{y}_i)^2}{n-1}}$

$a_0 = \bar{y} - a_1 \bar{x}$

$a_1 = \frac{\sum x_i y_i - \bar{x} \bar{y} n}{\sum x_i^2 - \bar{x}^2 n}$

## INTERPOLATION

USE 2 POINTS:  $P(x) = a_0 + a_1 x$

USE 3 POINTS:  $P(x) = a_0 + a_1 x + a_2 x^2$

USE 4 POINTS:  $P(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3$

DEGREE 1:

DEGREE 2:

DEGREE 3:

DEGREE n:

FORMULA:  $P(x) = \frac{(x-x_2)(x-x_3)\dots(x-x_n)}{(x_1-x_2)(x_1-x_3)\dots(x_1-x_n)} f(x_1) + \dots$

SPINES:  $P(x) = \frac{f(x_1)(x-x_2)\dots(x-x_n)}{x_1 - x_2 \dots x_1 - x_n}$

## ODE'S

EULER METHOD:  $y_{i+1} = y_i + f(x_i, y_i) \Delta x$

HEUN'S METHOD:  $y_{i+1} = y_i + f(x_i, y_i) \Delta x$

Runge-Kutta 4th order:  $y_{i+1} = y_i + \Delta x \frac{1}{6} (k_1 + 4k_2 + k_3 + k_4)$

Taylor Series:  $y(x+\Delta x) = y(x) + \Delta x y'(x) + \frac{\Delta x^2}{2} y''(x) + \dots$

## CLASSIC 4th ORDER RUNGE-KUTTA:

$y_{i+1} = y_i + \frac{\Delta x}{6} (k_1 + 4k_2 + k_3 + k_4)$

$k_1 = f(x_i, y_i)$

$k_2 = f(x_i + \frac{1}{2}\Delta x, y_i + \frac{1}{2}\Delta x k_1)$

$k_3 = f(x_i + \frac{1}{2}\Delta x, y_i + \Delta x k_2)$

$k_4 = f(x_i + \Delta x, y_i + \Delta x k_3)$

## PDE'S

### FINITE DIFFERENCE METHOD:



## EIGEN VALUES

$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$

CHARACTERISTIC EQUATION:  $\det(A - \lambda I) = 0$

$(a-\lambda)(d-\lambda) - bc = 0$

$\lambda^2 - (a+d)\lambda + (ad-bc) = 0$

EIGEN VALUES:  $\lambda = \frac{(a+d) \pm \sqrt{(a+d)^2 - 4(ad-bc)}}{2}$

EIGEN VECTORS:  $(A - \lambda I)v = 0$

1D HEAT CONDUCTION

TEMPERATURE:  $T(x, y, z, t)$

HEAT FLUX:  $q = -k \nabla T$

HEAT CONDUCTION EQUATION:  $\rho c_p \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + \dot{q}$

FINITE DIFFERENCE APPROXIMATION:

CENTRAL DIFFERENCE:  $\frac{\partial^2 T}{\partial x^2} \approx \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

RIGHT BOUNDARY B.C.:  $\frac{\partial T}{\partial x} = 0 \Rightarrow T_{i+1} = T_i$

LEFT BOUNDARY B.C.:  $\frac{\partial T}{\partial x} = 0 \Rightarrow T_{i-1} = T_i$

2D HEAT CONDUCTION

TEMPERATURE:  $T(x, y, z, t)$

HEAT FLUX:  $q = -k \nabla T$

HEAT CONDUCTION EQUATION:  $\rho c_p \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + \dot{q}$

FINITE DIFFERENCE APPROXIMATION:

CENTRAL DIFFERENCE:  $\frac{\partial^2 T}{\partial x^2} \approx \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

RIGHT BOUNDARY B.C.:  $\frac{\partial T}{\partial x} = 0 \Rightarrow T_{i+1} = T_i$

LEFT BOUNDARY B.C.:  $\frac{\partial T}{\partial x} = 0 \Rightarrow T_{i-1} = T_i$

5th ROW OF A MATRIX

LOCAL THERMODYNAMIC EQUILIBRIUM (LTE)

FINITE DIFFERENCE APPROXIMATION:

CENTRAL DIFFERENCE:  $\frac{\partial^2 T}{\partial x^2} \approx \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

RIGHT BOUNDARY B.C.:  $\frac{\partial T}{\partial x} = 0 \Rightarrow T_{i+1} = T_i$

LEFT BOUNDARY B.C.:  $\frac{\partial T}{\partial x} = 0 \Rightarrow T_{i-1} = T_i$

[A] MATRIX:

INTERNAL NODES:  $-2T_{i,j} + T_{i,j+1} + T_{i,j-1} + T_{i+1,j} + T_{i-1,j} = -2\Delta x^2 \ddot{T}_{i,j}$

RIGHT BOUNDARY B.C.:  $-2T_{i,N} + T_{i,N-1} + T_{i,N+1} = -2\Delta x^2 \ddot{T}_{i,N}$

LEFT BOUNDARY B.C.:  $-2T_{i,1} + T_{i,2} + T_{i,0} = -2\Delta x^2 \ddot{T}_{i,1}$

FINITE DIFFERENCE

CENTRAL FINITE-DIFFERENCE DERIVATIVE:

FIRST:  $f'(x) = \frac{f(x_2) - f(x_1)}{\Delta x}$

SECOND:  $f''(x) = \frac{f(x_2) - 2f(x_1) + f(x_0))}{\Delta x^2}$

# Numerical Methods And Analysis

**Petre Teodorescu, Nicolae-Doru  
Stanescu, Nicolae Pandrea**



## **Numerical Methods And Analysis:**

*An Introduction to Numerical Methods and Analysis* James F. Epperson, 2013-06-06 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

*Analysis of Numerical Methods* Eugene Isaacson, Herbert Bishop Keller, 2012-04-26 This excellent text for advanced undergraduate and graduate students covers norms numerical solutions of linear systems and matrix factoring eigenvalues and eigenvectors polynomial approximation and more Many examples and problems 1966 edition

**Numerical Analysis** M. Schatzman, 2002 Numerical analysis explains why numerical computations work or fail This book is divided into four parts Part I starts with a guided tour of floating number systems and machine arithmetic The exponential and the logarithm are constructed from scratch to present a new point of view on questions well known to the reader and the needed knowledge of linear algebra is summarized Part II starts with polynomial approximation polynomial interpolation mean square approximation splines It then deals with Fourier series providing the trigonometric version of least square approximations and one of the most important numerical algorithms the fast Fourier transform Any scientific computation program spends most of its time solving linear systems or approximating the solution of linear systems even when trying to solve non linear systems Part III is therefore about numerical linear algebra while Part IV treats a selection of non linear or complex problems resolution of linear equations and systems ordinary differential equations single step and multi step schemes and an introduction to partial differential equations The book has been written having in mind the advanced undergraduate students in mathematics who are interested in the spice and spirit of numerical analysis The book does not assume previous knowledge of numerical methods It will also be useful to scientists and engineers wishing to learn what mathematics has to say about the reason why their numerical methods work or fail

**Numerical Methods and**

**Analysis** James L. Buchanan, Peter R. Turner, 1992 Intended for a first course in numerical methods or numerical analysis taken by junior and senior level students this book assumes a knowledge of calculus linear algebra and differential equations It covers numerical approximation interpolation graphics and parallel computing The interplay between hardware and software considerations in numerical algorithm design recurs throughout A portion of the programs in the book are written in Turbo Pascal the remainder are pseudocode or generalized algorithms Programs used in the text will be available on a disk for instructors to use and copy

**An Introduction to Numerical Methods and Analysis, Solutions Manual** James F. Epperson, 2014-08-28 A solutions manual to accompany An Introduction to Numerical Methods and Analysis Second Edition An Introduction to Numerical Methods and Analysis Second Edition reflects the latest trends in the field includes new material and revised exercises and offers a unique emphasis on applications The author clearly explains how to both construct and evaluate approximations for accuracy and performance which are key skills in a variety of fields A wide range of higher level methods and solutions including new topics such as the roots of polynomials spectral collocation finite element ideas and Clenshaw Curtis quadrature are presented from an introductory perspective and the Second Edition also features Chapters and sections that begin with basic elementary material followed by gradual coverage of more advanced material Exercises ranging from simple hand computations to challenging derivations and minor proofs to programming exercises Widespread exposure and utilization of MATLAB An appendix that contains proofs of various theorems and other material

Theory and Applications of Numerical Analysis G. M. Phillips, Peter J. Taylor, 1996-07-05 Theory and Applications of Numerical Analysis is a self contained Second Edition providing an introductory account of the main topics in numerical analysis The book emphasizes both the theorems which show the underlying rigorous mathematics and the algorithms which define precisely how to program the numerical methods Both theoretical and practical examples are included a unique blend of theory and applications two brand new chapters on eigenvalues and splines inclusion of formal algorithms numerous fully worked examples a large number of problems many with solutions

**Numerical Methods for Ordinary Differential Equations** J. C. Butcher, 2008-04-15 In recent years the study of numerical methods for solving ordinary differential equations has seen many new developments This second edition of the author's pioneering text is fully revised and updated to acknowledge many of these developments It includes a complete treatment of linear multistep methods whilst maintaining its unique and comprehensive emphasis on Runge Kutta methods and general linear methods Although the specialist topics are taken to an advanced level the entry point to the volume as a whole is not especially demanding Early chapters provide a wide ranging introduction to differential equations and difference equations together with a survey of numerical differential equation methods based on the fundamental Euler method with more sophisticated methods presented as generalizations of Euler Features of the book include Introductory work on differential and difference equations A comprehensive introduction to the theory and practice of solving ordinary differential equations numerically A detailed analysis of Runge Kutta methods

and of linear multistep methods A complete study of general linear methods from both theoretical and practical points of view The latest results on practical general linear methods and their implementation A balance between informal discussion and rigorous mathematical style Examples and exercises integrated into each chapter enhancing the suitability of the book as a course text or a self study treatise Written in a lucid style by one of the worlds leading authorities on numerical methods for ordinary differential equations and drawing upon his vast experience this new edition provides an accessible and self contained introduction ideal for researchers and students following courses on numerical methods engineering and other sciences

**Solutions Manual to accompany An Introduction to Numerical Methods and Analysis** James F. Epperson, 2013-10-21 A solutions manual to accompany An Introduction to Numerical Methods and Analysis Second Edition An Introduction to Numerical Methods and Analysis Second Edition reflects the latest trends in the field includes new material and revised exercises and offers a unique emphasis on applications The author clearly explains how to both construct and evaluate approximations for accuracy and performance which are key skills in a variety of fields A wide range of higher level methods and solutions including new topics such as the roots of polynomials spectral collocation finite element ideas and Clenshaw Curtis quadrature are presented from an introductory perspective and the Second Edition also features Chapters and sections that begin with basic elementary material followed by gradual coverage of more advanced material Exercises ranging from simple hand computations to challenging derivations and minor proofs to programming exercises Widespread exposure and utilization of MATLAB An appendix that contains proofs of various theorems and other material

**Applied Numerical Analysis** Curtis F. Gerald, Patrick O. Wheatley, 1984 **Numerical Analysis with Applications in Mechanics and Engineering** Petre Teodorescu, Nicolae-Doru Stanescu, Nicolae Pandrea, 2013-06-04 NUMERICAL ANALYSIS WITH APPLICATIONS IN MECHANICS AND ENGINEERING A much needed guide on how to use numerical methods to solve practical engineering problems Bridging the gap between mathematics and engineering Numerical Analysis with Applications in Mechanics and Engineering arms readers with powerful tools for solving real world problems in mechanics physics and civil and mechanical engineering Unlike most books on numerical analysis this outstanding work links theory and application explains the mathematics in simple engineering terms and clearly demonstrates how to use numerical methods to obtain solutions and interpret results Each chapter is devoted to a unique analytical methodology including a detailed theoretical presentation and emphasis on practical computation Ample numerical examples and applications round out the discussion illustrating how to work out specific problems of mechanics physics or engineering Readers will learn the core purpose of each technique develop hands on problem solving skills and get a complete picture of the studied phenomenon Coverage includes How to deal with errors in numerical analysis Approaches for solving problems in linear and nonlinear systems Methods of interpolation and approximation of functions Formulas and calculations for numerical differentiation and integration Integration of ordinary and partial differential equations Optimization methods and solutions

for programming problems Numerical Analysis with Applications in Mechanics and Engineering is a one of a kind guide for engineers using mathematical models and methods as well as for physicists and mathematicians interested in engineering problems *Introduction to Precise Numerical Methods* Oliver Aberth,2007-04-11 Precise numerical analysis may be defined as the study of computer methods for solving mathematical problems either exactly or to prescribed accuracy This book explains how precise numerical analysis is constructed The book also provides exercises which illustrate points from the text and references for the methods presented Clearer simpler descriptions and explanations of the various numerical methods Two new types of numerical problems accurately solving partial differential equations with the included software and computing line integrals in the complex plane **Numerical Methods and Analysis of Multiscale Problems**

Alexandre L. Madureira,2017-02-15 This book is about numerical modeling of multiscale problems and introduces several asymptotic analysis and numerical techniques which are necessary for a proper approximation of equations that depend on different physical scales Aimed at advanced undergraduate and graduate students in mathematics engineering and physics or researchers seeking a no nonsense approach it discusses examples in their simplest possible settings removing mathematical hurdles that might hinder a clear understanding of the methods The problems considered are given by singular perturbed reaction advection diffusion equations in one and two dimensional domains partial differential equations in domains with rough boundaries and equations with oscillatory coefficients This work shows how asymptotic analysis can be used to develop and analyze models and numerical methods that are robust and work well for a wide range of parameters

*Numerical Analysis Or Numerical Method in Symmetry* Clemente Cesarano,2020-02-21 This Special Issue focuses mainly on techniques and the relative formalism typical of numerical methods and therefore of numerical analysis more generally These fields of study of mathematics represent an important field of investigation both in the field of applied mathematics and even more exquisitely in the pure research of the theory of approximation and the study of polynomial relations as well as in the analysis of the solutions of the differential equations both ordinary and partial derivatives Therefore a substantial part of research on the topic of numerical analysis cannot exclude the fundamental role played by approximation theory and some of the tools used to develop this research In this Special Issue we want to draw attention to the mathematical methods used in numerical analysis such as special functions orthogonal polynomials and their theoretical tools such as Lie algebra to study the concepts and properties of some special and advanced methods which are useful in the description of solutions of linear and nonlinear differential equations A further field of investigation is dedicated to the theory and related properties of fractional calculus with its adequate application to numerical methods **Numerical Analysis for Engineers** Bilal Ayyub,Richard H. McCuen,2015-09-18 Numerical Analysis for Engineers Methods and Applications demonstrates the power of numerical methods in the context of solving complex engineering and scientific problems The book helps to prepare future engineers and assists practicing engineers in understanding the fundamentals of numerical methods especially their

applications limitations      Numerical Methods for Ordinary Differential Equations John Charles Butcher,2016      **B-Series**  
John C. Butcher,2021-04-01 B series also known as Butcher series are an algebraic tool for analysing solutions to ordinary differential equations including approximate solutions Through the formulation and manipulation of these series properties of numerical methods can be assessed Runge Kutta methods in particular depend on B series for a clean and elegant approach to the derivation of high order and efficient methods However the utility of B series goes much further and opens a path to the design and construction of highly accurate and efficient multivalued methods This book offers a self contained introduction to B series by a pioneer of the subject After a preliminary chapter providing background on differential equations and numerical methods a broad exposition of graphs and trees is presented This is essential preparation for the third chapter in which the main ideas of B series are introduced and developed In chapter four algebraic aspects are further analysed in the context of integration methods a generalization of Runge Kutta methods to infinite index sets Chapter five on explicit and implicit Runge Kutta methods contrasts the B series and classical approaches Chapter six on multivalued methods gives a traditional review of linear multistep methods and expands this to general linear methods for which the B series approach is both natural and essential The final chapter introduces some aspects of geometric integration from a B series point of view Placing B series at the centre of its most important applications makes this book an invaluable resource for scientists engineers and mathematicians who depend on computational modelling not to mention computational scientists who carry out research on numerical methods in differential equations In addition to exercises with solutions and study notes a number of open ended projects are suggested This combination makes the book ideal as a textbook for specialised courses on numerical methods for differential equations as well as suitable for self study      An Introduction to Numerical Analysis, 2nd Ed Kendall E. Atkinson,2008-09 Market\_Desc Mathematics Students Instructors About The Book This Second Edition of a standard numerical analysis text retains organization of the original edition but all sections have been revised some extensively and bibliographies have been updated New topics covered include optimization trigonometric interpolation and the fast Fourier transform numerical differentiation the method of lines boundary value problems the conjugate gradient method and the least squares solutions of systems of linear equations      An Introduction to Numerical Methods and Analysis Set James F. Epperson,2013-10-09 This set includes An Introduction to Numerical Methods and Analysis 2nd Edition Roots of Polynomials I Radial Basis Function Interpolation Tension Splines An Introduction to Galerkin Finite Element Ideas for BVPs Broyden s Method Roots of Polynomials II Spectral collocation methods for PDEs Algebraic Multigrid Method Trigonometric interpolation Fourier analysis and Monte Carlo methods      Numerical Analysis of Wavelet Methods A. Cohen,2003-04-29 Since their introduction in the 1980 s wavelets have become a powerful tool in mathematical analysis with applications such as image compression statistical estimation and numerical simulation of partial differential equations One of their main attractive features is the ability to accurately represent fairly general functions with a small number of adaptively chosen

wavelet coefficients as well as to characterize the smoothness of such functions from the numerical behaviour of these coefficients The theoretical pillar that underlies such properties involves approximation theory and function spaces and plays a pivotal role in the analysis of wavelet based numerical methods This book offers a self contained treatment of wavelets which includes this theoretical pillar and its applications to the numerical treatment of partial differential equations Its key features are 1 Self contained introduction to wavelet bases and related numerical algorithms from the simplest examples to the most numerically useful general constructions 2 Full treatment of the theoretical foundations that are crucial for the analysis of wavelets and other related multiscale methods function spaces linear and nonlinear approximation interpolation theory 3 Applications of these concepts to the numerical treatment of partial differential equations multilevel preconditioning sparse approximations of differential and integral operators adaptive discretization strategies

**INTRODUCTORY METHODS OF NUMERICAL ANALYSIS, FIFTH EDITION** SASTRY, S. S., 2012-06-12 This thoroughly revised and updated text now in its 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

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