

NUMERICAL METHODS

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

LEAST SQUARES REGRESSION

Goal: minimize the sum of the squares of the residual errors.



$$S_r = \sum_{i=1}^n d_i = \sum_{i=1}^n (y_i - a_0 - a_1 x_i)$$

Residual $d_i = y_i - \hat{y}_i$

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

$$Q_0 = \sum_{i=1}^n y_i^2 \quad Q_1 = \sum_{i=1}^n x_i y_i \quad Q_2 = \sum_{i=1}^n x_i^2$$

POLYNOMIAL QUADRATIC REGRESSION:



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

Take derivative of S_r to find minimum

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

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

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

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

Use Gauss-Jordan elimination

STANDARD ERROR:

$$S_{y_1} = \sqrt{\frac{S_r}{n-2}} \quad S_{y_2} = \sqrt{\frac{S_r (1-x_i^2)}{n-2}}$$

STANDARD DEVIATION:

$$S_y = \sqrt{\frac{S_r}{n-1}} \quad S_x = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

$$a_0 = \bar{y} - a_1 \bar{x} \quad a_1 = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2}$$

INTERPOLATION

Use a polynomial $P(x)$



$$P(x) = a_0 + a_1 x + a_2 x^2 + \dots + a_n x^n$$

- Order: $n=1$ (line), $n=2$ (parabola), $n=3$ (cubic), $n=4$ (quartic)
- Turns: $n=1$ (0), $n=2$ (1), $n=3$ (2), $n=4$ (3)

ODE'S

Euler's Method

$$\frac{dy}{dx} = f(x,y) \quad y_{i+1} = y_i + f(x_i, y_i) \Delta x$$

Runge-Kutta Method

$$\frac{dy}{dx} = f(x,y) \quad y_{i+1} = y_i + f(x_i, y_i) \Delta x$$

$$\frac{dy}{dx} = f(x,y) \quad y_{i+1} = y_i + f(x_i, y_i) \Delta x$$

$$\frac{dy}{dx} = f(x,y) \quad y_{i+1} = y_i + f(x_i, y_i) \Delta x$$

$$y = \frac{y_i^2 + 2x_i y_i + f(x_i, y_i) \Delta x}{2}$$

$$y_{i+1} = y_i + \frac{f(x_i, y_i) + f(x_{i+1}, y_{i+1})}{2} \Delta x$$

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

Classic 4th order Runge-Kutta

$$y_{i+1} = y_i + \frac{\Delta x}{4} (k_1 + 2k_2 + 2k_3 + k_4)$$

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

$$k_3 = f(x_i + \frac{1}{2}\Delta x, y_i + \Delta x k_1 + \frac{1}{2}\Delta x k_2)$$

$$k_4 = f(x_i + \Delta x, y_i + \Delta x k_1 + \Delta x k_2 + \frac{1}{2}\Delta x k_3)$$

Local truncation error: Δx^5
 Global truncation error: Δx^4

PDE'S

Finite Difference Method



Central Difference: $\frac{\partial^2 u}{\partial x^2} \approx \frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta x^2}$

Forward Difference: $\frac{\partial u}{\partial x} \approx \frac{u_i - u_{i-1}}{\Delta x}$

Backward Difference: $\frac{\partial u}{\partial x} \approx \frac{u_{i+1} - u_i}{\Delta x}$

Central Difference: $\frac{\partial^2 u}{\partial x^2} \approx \frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta x^2}$

$$u_{i+1} = u_i + \Delta x \frac{\partial u}{\partial x} + \frac{\Delta x^2}{2} \frac{\partial^2 u}{\partial x^2} + \dots$$

$$u_{i-1} = u_i - \Delta x \frac{\partial u}{\partial x} + \frac{\Delta x^2}{2} \frac{\partial^2 u}{\partial x^2} - \dots$$

$$u_{i+1} - 2u_i + u_{i-1} = \Delta x^2 \frac{\partial^2 u}{\partial x^2} + \mathcal{O}(\Delta x^4)$$

$$u_{i+1} - 2u_i + u_{i-1} = \Delta x^2 \frac{\partial^2 u}{\partial x^2} + \mathcal{O}(\Delta x^4)$$

$$u_{i+1} - 2u_i + u_{i-1} = \Delta x^2 \frac{\partial^2 u}{\partial x^2} + \mathcal{O}(\Delta x^4)$$

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$$u_{i+1} - 2u_i + u_{i-1} = \Delta x^2 \frac{\partial^2 u}{\partial x^2} + \mathcal{O}(\Delta x^4)$$

EIGEN VALUES

$\lambda = \text{Eigenvalue}$

$$\begin{bmatrix} a_{11} - \lambda & a_{12} \\ a_{21} & a_{22} - \lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$\det(A - \lambda I) = 0$$

$$\lambda = \frac{a+d}{2} \pm \sqrt{\left(\frac{a-d}{2}\right)^2 + bc}$$

Single 2x2

$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$\det(A - \lambda I) = 0$$

$$\lambda = \frac{a+d}{2} \pm \sqrt{\left(\frac{a-d}{2}\right)^2 + bc}$$

Full matrix with given

$$\begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$x_1 + x_2 = 0 \Rightarrow x_1 = -x_2$$

$$x_1 + x_2 = 0 \Rightarrow x_1 = -x_2$$

$$x_1 = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$$

Eigen values

$$\begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$-x_1 + x_2 = 0 \Rightarrow x_1 = x_2$$

$$x_1 + -1x_2 = 0 \Rightarrow x_1 = x_2$$

$$x_1 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

$$A = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$$

5th row of a matrix

$$\begin{bmatrix} 0 & -1 & 0 & -1 & 1 & -1 & 0 & -1 & 0 \end{bmatrix} \begin{bmatrix} u \\ v \\ w \\ x \\ y \\ z \end{bmatrix} = 0$$

$$-v - x + y - z = 0$$

$$-v - x + y - z = 0$$

$$-v - x + y - z = 0$$

$$-v - x + y - z = 0$$

$$-v - x + y - z = 0$$

TRUNCATION ERROR

$$\text{Error} = \frac{f(x_{i+1}) - f(x_i)}{\Delta x}$$

$$f(x) = f(x_i) + \Delta x f'(x_i) + \frac{\Delta x^2}{2} f''(x_i) + \dots$$

$$f(x_{i+1}) - f(x_i) = \Delta x f'(x_i) + \frac{\Delta x^2}{2} f''(x_i) + \dots$$

$$f(x_{i+1}) - f(x_i) = \Delta x f'(x_i) + \frac{\Delta x^2}{2} f''(x_i) + \dots$$

Numerical Mathematics

H. Rutishauser



Numerical Mathematics:

Numerical Mathematics Alfio Quarteroni, Riccardo Sacco, Fausto Saleri, 2010-11-30 This book provides the mathematical foundations of numerical methods and demonstrates their performance on examples exercises and real life applications This is done using the MATLAB software environment which allows an easy implementation and testing of the algorithms for any specific class of problems The book is addressed to students in Engineering Mathematics Physics and Computer Sciences In the second edition of this extremely popular textbook on numerical analysis the readability of pictures tables and program headings has been improved Several changes in the chapters on iterative methods and on polynomial approximation have also been

An Introduction to Numerical Mathematics Eduard L. Stiefel, 2014-05-12 An Introduction to Numerical Mathematics provides information pertinent to the fundamental aspects of numerical mathematics This book covers a variety of topics including linear programming linear and nonlinear algebra polynomials numerical differentiation and approximations Organized into seven chapters this book begins with an overview of the solution of linear problems wherein numerical mathematics provides very effective algorithms consisting of finitely many computational steps This text then examines the method for the direct solution of a definite problem Other chapters consider the determination of frequencies in freely oscillating mechanical or electrical systems This book discusses as well eigenvalue problems for oscillatory systems of finitely many degrees of freedom which can be reduced to algebraic equations The final chapter deals with the approximate representation of a function $f(x)$ given by I values as in the form of a table This book is a valuable resource for physicists mathematicians theoreticians engineers and research workers

Basic Numerical Mathematics J. Todd, 2013-03-13 There is no doubt nowadays that numerical mathematics is an essential component of any educational program It is probably more efficient to present such material after a strong grasp of at least linear algebra and calculus has already been attained but at this stage those not specializing in numerical mathematics are often interested in getting more deeply into their chosen field than in developing skills for later use An alternative approach is to incorporate the numerical aspects of linear algebra and calculus as these subjects are being developed Long experience has persuaded us that a third attack on this problem is the best and this is developed in the present two volumes which are however easily adaptable to other circumstances The approach we prefer is to treat the numerical aspects separately but after some theoretical background This is often desirable because of the shortage of persons qualified to present the combined approach and also because the numerical approach provides an often welcome change which however in addition can lead to better appreciation of the fundamental concepts For instance in a 6 quarter course in Calculus and Linear Algebra the material in Volume 1 can be handled in the third quarter and that in Volume 2 in the fifth or sixth quarter

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 *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 **A Survey of Numerical Mathematics, Volume**

I David M. Young,Robert Todd Gregory,2012-08-09 Volume 1 of two volume set Broad self contained coverage of computer oriented numerical algorithms for solving various types of mathematical problems in linear algebra ordinary and partial differential equations much more Exercises *Lectures on Numerical Mathematics* H. Rutishauser,2012-12-06 The present book is an edition of the manuscripts to the courses Numerical Methods I and Numerical Mathematics I and II which Professor H Rutishauser held at the E T H in Zurich The first named course was newly conceived in the spring semester of 1970 and intended for beginners while the two others were given repeatedly as elective courses in the sixties For an understanding of most chapters the fundamentals of linear algebra and calculus suffice In some places a little complex variable theory is used in addition However the reader can get by without any knowledge of functional analysis The first seven chapters discuss the direct solution of systems of linear equations the solution of nonlinear systems least squares prob

lems interpolation by polynomials numerical quadrature and approximation by Chebyshev series and by Remez algorithm
 The remaining chapters include the treatment of ordinary and partial differential equations the iterative solution of linear
 equations and a discussion of eigen value problems In addition there is an appendix dealing with the qd algorithm and with
 an axiomatic treatment of computer arithmetic

Numerical Mathematics and Computing E. (University of Texas at
 Austin) Cheney, David (University of Texas at Austin) Kincaid, 2020-08 Authors Ward Cheney and David Kincaid show students
 of science and engineering the potential computers have for solving numerical problems and give them ample opportunities
 to hone their skills in programming and problem solving NUMERICAL MATHEMATICS AND COMPUTING 7th Edition also
 helps students learn about errors that inevitably accompany scientific computations and arms them with methods for
 detecting predicting and controlling these errors

**Fundamentals of Numerical Mathematics for Physicists and
 Engineers** Alvaro Meseguer, 2020-05-14 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
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 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

Basic Numerical Methods R. E. Scraton, 1984 Numbers errors and accuracy
 Iterative methods Solution of equations Simultaneous equations I Simultaneous equations II Numerical integration

Differential equations I Differential equations II **Numerical Mathematics and Applications** J. Vignes,R. Vichnevetsky,2014-06-28 Numerical Mathematics and Applications *Numerical Methods that Work* Forman S. Acton,1990 A commonsense approach to numerical algorithms for the solution of equations **Classical and Modern Numerical Analysis** Azmy S. Ackleh,Edward James Allen,R. Baker Kearfott,Padmanabhan Seshaiyer,2009-07-20 Classical and Modern Numerical Analysis Theory Methods and Practice provides a sound foundation in numerical analysis for more specialized topics such as finite element theory advanced numerical linear algebra and optimization It prepares graduate students for taking doctoral examinations in numerical analysis The text covers the main areas of introductory numerical analysis including the solution of nonlinear equations numerical linear algebra ordinary differential equations approximation theory numerical integration and boundary value problems Focusing on interval computing in numerical analysis it explains interval arithmetic interval computation and interval algorithms The authors illustrate the concepts with many examples as well as analytical and computational exercises at the end of each chapter This advanced graduate level introduction to the theory and methods of numerical analysis supplies the necessary background in numerical methods so that students can apply the techniques and understand the mathematical literature in this area Although the book is independent of a specific computer program MATLAB code is available on the authors website to illustrate various concepts **Frontiers of Numerical Mathematics** Rudolph Ernest Langer,1960 **Numerical Analysis** John Todd,2014-05-10 Basic Numerical Mathematics Volume 1 Numerical Analysis focuses on numerical analysis with emphasis on the ideas of controlled computational experiments and bad examples The concepts of convergence and continuity are discussed along with the rate of convergence acceleration and asymptotic series The more traditional topics of interpolation quadrature and differential equations are also explored Comprised of 10 chapters this volume begins with an analysis of the algorithms of Gauss Borchardt and Carlson in relation to the rate of convergence The reader is then introduced to orders of magnitude and rates of convergence recurrence relations for powers and the solution of equations Subsequent chapters deal with uniform convergence and approximation the acceleration processes of Aitken and Euler asymptotic series interpolation and quadrature The final chapter is devoted to linear difference equations with constant coefficients along with differentiation and differential equations This book will be of interest to mathematicians and students of mathematics **Elementary Numerical Mathematics for Programmers and Engineers** Gisbert Stoyan,Agnes Baran,2016-11-09 This book covers the basics of numerical methods while avoiding the definition theorem proof style and instead focusing on numerical examples and simple pseudo codes The book is divided into ten chapters Starting with floating number calculations and continuing up to ordinary differential equations including Euler backwards The final chapter discusses practical error estimations Exercises including several in MATLAB are provided at the end of each chapter Suitable for readers with minimal mathematical knowledge the book not only offers an elementary introduction to numerical mathematics for programmers and engineers but also provides

supporting material for students and teachers of mathematics Methods of Numerical Mathematics G.I.

Marchuk,1982-05-25 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 mathematical 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 primarily 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 Differential Equations and Numerical Mathematics

Guriĭ Ivanovich Marchuk,1982 Cubature formulae and functional analysis Differential equations Numerical mathematics

The Concept of Stability in Numerical Mathematics Wolfgang Hackbusch,2014-02-06 In this book the author compares the meaning of stability in different subfields of numerical mathematics Concept of Stability in numerical mathematics opens by examining the stability of finite algorithms A more precise definition of stability holds for quadrature and interpolation methods which the following chapters focus on The discussion then progresses to the numerical treatment of ordinary differential equations ODEs While one step methods for ODEs are always stable this is not the case for hyperbolic or parabolic differential equations which are investigated next The final chapters discuss stability for discretisations of elliptic differential equations and integral equations In comparison among the subfields we discuss the practical importance of stability and the possible conflict between higher consistency order and stability *Numerical Methods for Mathematics, Science, and Engineering* John H. Mathews,1992 Provides an introduction to numerical analysis with a particular emphasis on why numerical methods work and what their limitations are In a straightforward presentation the book shows readers how the mathematics of calculus and linear algebra are implemented in computer algorithms

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Numerical Mathematics Introduction

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