

# NUMERICAL METHODS

C / KAPPA 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 Error =  $y_i - \hat{y}_i$

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

$$a_0 = \frac{\sum y_i}{n} - a_1 \frac{\sum x_i}{n} \Rightarrow a_0 = 5 - 0.8$$

## STANDARD ERROR:

$$S_{y_1} = \sqrt{\frac{\sum y_i^2}{n-2}} \quad S_{y_2} = \sqrt{\frac{\sum (y_i - \hat{y}_i)^2}{n-2}}$$

## STANDARD DEVIATION:

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

$$a_0 = 5 - 0.8x$$

## 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 the error.

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

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

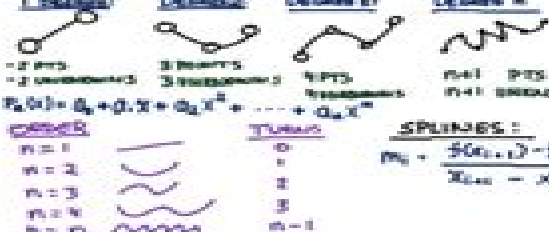
$$\frac{\partial S_r}{\partial a_2} = -2(\sum y_i x_i^2 - \sum a_0 x_i^2 - a_1 \sum x_i^3 - a_2 \sum x_i^4) = 0$$

$$\begin{bmatrix} \sum x_i^0 & \sum x_i^1 & \sum x_i^2 \\ \sum x_i^1 & \sum x_i^2 & \sum x_i^3 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum y_i x_i \\ \sum y_i x_i^2 \end{bmatrix}$$

Matrix method

## INTERPOLATION

Use a polynomial  $P(x)$



## ODE'S

### Euler's Method

$$\frac{dy}{dx} = f(x,y) \quad y_{n+1} = y_n + f(x_n, y_n) \Delta x$$

### Runge-Kutta Method

$$y' = f(x,y)$$

$$k_1 = f(x_n, y_n)$$

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

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

$$k_4 = f(x_n + \Delta x, y_n + \Delta x k_3)$$

$$y_{n+1} = y_n + \Delta x \frac{k_1 + 2k_2 + 2k_3 + k_4}{4}$$

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

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

$$k_1 = f(x_n, y_n)$$

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

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

$$k_4 = f(x_n + \Delta x, y_n + \Delta x k_3)$$

## PDE'S

### Finite Difference Method



## EIGEN VALUES

$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$\det(A - \lambda I) = \begin{vmatrix} a-\lambda & b \\ c & d-\lambda \end{vmatrix} = (a-\lambda)(d-\lambda) - bc = 0$$

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

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

Single 2x2:

$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$\det(A - \lambda I) = \begin{vmatrix} a-\lambda & b \\ c & d-\lambda \end{vmatrix} = 0$$

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

Two eigen values with same

$$\begin{bmatrix} a-\lambda & b \\ c & d-\lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$(a-\lambda)x_1 + bx_2 = 0$$

$$cx_1 + (d-\lambda)x_2 = 0$$

Two eigen values

$$\begin{bmatrix} a-\lambda & b \\ c & d-\lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$-ax_1 + bx_2 = 0 \Rightarrow x_2 = \frac{a}{b} x_1$$

$$(x_1, -\frac{1}{b} x_1) \Rightarrow x_1 = 1, x_2 = -\frac{1}{b}$$

**RIGHT BOUNDARY B.C.**

Top boundary:  $T = T_0$

Bottom boundary:  $T = T_1$

Central difference:

$$u_{i,j+1} = u_{i,j} - \Delta x u_{x,i,j} - \Delta y u_{y,i,j} + u_{i,j} + \Delta x \Delta y$$

$$u_{i,j-1} = u_{i,j} + \Delta x u_{x,i,j} - \Delta y u_{y,i,j} + u_{i,j} - \Delta x \Delta y$$

**INTERNAL B.C.**

Central difference:

$$u_{i,j} = \frac{u_{i+1,j} + u_{i-1,j} + u_{i,j+1} + u_{i,j-1} - 4u_{i,j} + \Delta x^2 u_{xx} + \Delta y^2 u_{yy}}{4}$$

**RIGHT BOUNDARY B.C.**

$$\frac{\partial u}{\partial x} = 0 \Rightarrow \frac{u_{i+1,j} - u_{i-1,j}}{2\Delta x} = 0$$

$$u_{i+1,j} = u_{i-1,j}$$

**5th row of a matrix**

$$\begin{bmatrix} 0 & -1 & 0 & -1 & 4 & -1 & 0 & -1 & 0 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \\ u_6 \\ u_7 \\ u_8 \\ u_9 \end{bmatrix} = 0$$

**[A] MATRIX:**

Centered finite-diff eqs:

$$-2u_{i,j+1} + 4u_{i,j} - 2u_{i,j-1} - u_{i+1,j} - u_{i-1,j} = -2\Delta x \Delta y$$

$$-2u_{i,j+1} + 4u_{i,j} - u_{i+1,j} - u_{i-1,j} = -2\Delta x \Delta y$$

$$-u_{i+1,j} - u_{i-1,j} + 4u_{i,j} - 2u_{i,j+1} - 2u_{i,j-1} = -2\Delta x \Delta y$$

$$-u_{i+1,j} - u_{i-1,j} + 4u_{i,j} - 2u_{i,j+1} = -2\Delta x \Delta y$$

**5th row of a matrix**

Centered finite-diff eqs:

$$f(x) = \frac{f(x+\Delta x) - f(x-\Delta x)}{2\Delta x}$$

$$f(x) = \frac{f(x+\Delta x) + 3f(x) - 3f(x-\Delta x) + f(x)}{4\Delta x}$$

# Numerical Analysis Using R

**Yicheng Fang**



## **Numerical Analysis Using R:**

## **Numerical Analysis Using R** Book Review: Unveiling the Power of Words

In a global driven by information and connectivity, the power of words has are more evident than ever. They have the capability to inspire, provoke, and ignite change. Such is the essence of the book **Numerical Analysis Using R**, a literary masterpiece that delves deep in to the significance of words and their effect on our lives. Written by a renowned author, this captivating work takes readers on a transformative journey, unraveling the secrets and potential behind every word. In this review, we shall explore the book is key themes, examine its writing style, and analyze its overall affect readers.

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