

# 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)



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

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

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

## STANDARD ERROR:

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

## STANDARD DEVIATION:

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

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

## INTERPOLATION

| Order | Degree | Nodes | Polynomial Form                                      |
|-------|--------|-------|--|
| 1     | 0      | 2     | $P_0(x) = a_0 + a_1 x$                               |
| 2     | 1      | 3     | $P_1(x) = a_0 + a_1 x + a_2 x^2$                     |
| 3     | 2      | 4     | $P_2(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3$           |
| 4     | 3      | 5     | $P_3(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4$ |

## ODE'S

**Euler's Method:**  

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

## Runge-Kutta Method:

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

$$y' = \frac{y^2 + 2x}{2} \quad f(x, y) = \frac{y^2 + 2x}{2}$$

**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:

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

$$k_1 = f(x_i, y_i)$$

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

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

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

## POLYNOMIAL QUADRATIC REGRESSION:



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

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

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

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

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

## EIGEN VALUES

**Example 2x2:**  

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

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

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

**Example 3x3:**  

$$\begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

## PDE'S

### FINITE DIFFERENCE METHOD:

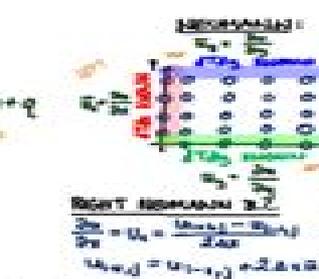


**Central Difference:**  

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

**Right Boundary B.C.:**  

$$u_{i,j} = u_{i+1,j} = 0$$



**Bottom Boundary B.C.:**  

$$u_{i,j} = u_{i,j+1} = 0$$

**Top Boundary B.C.:**  

$$u_{i,j} = u_{i,j-1} = 0$$

**Left Boundary B.C.:**  

$$u_{i,j} = u_{i-1,j} = 0$$

**[A] MATRIX:**  

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

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

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

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

**TRUNCATION ERROR:**  

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

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

# Analysis Of Numerical Methods

**Brendan G. Carr**



## **Analysis Of Numerical Methods:**

## Decoding **Analysis Of Numerical Methods**: Revealing the Captivating Potential of Verbal Expression

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