

# 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:

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

## POLYNOMIAL QUADRATIC REGRESSION:



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

Take derivatives of  $S_r$  to find the error.

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

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

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

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

Matrix inversion to find coefficients.

## INTERPOLATION

Use a polynomial  $P(x)$



## 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

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

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

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

$$k_3 = f(x_i + \Delta x, y_i + \Delta x k_2)$$

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

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

$$y_{i+1} = y_i + \Delta x \left( \frac{1}{4} k_1 + \frac{3}{4} k_2 + \frac{3}{4} k_3 + \frac{1}{4} k_4 \right)$$

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

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

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

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

## PDE'S

### Finite Difference Method



## EIGEN VALUES

$\lambda = \text{Eigen Value}$

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

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

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

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

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

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

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

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

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

**RIGHT BOUNDARY B.C.**

Top boundary:  $T(x,0) = T_0$

Bottom boundary:  $T(x,L) = T_1$

Central difference:  $T_{i,j} = \frac{T_{i,j+1} + T_{i,j-1} + T_{i+1,j} + T_{i-1,j}}{4}$

Left boundary B.C.:  $T_{0,j} = T_0$

Right boundary B.C.:  $T_{M,j} = T_1$

**LEFT BOUNDARY B.C.**

Top boundary:  $T(x,0) = T_0$

Bottom boundary:  $T(x,L) = T_1$

Central difference:  $T_{i,j} = \frac{T_{i,j+1} + T_{i,j-1} + T_{i+1,j} + T_{i-1,j}}{4}$

Left boundary B.C.:  $T_{0,j} = T_0$

Right boundary B.C.:  $T_{M,j} = T_1$

**TOP BOUNDARY B.C.**

Top boundary:  $T(x,0) = T_0$

Bottom boundary:  $T(x,L) = T_1$

Central difference:  $T_{i,j} = \frac{T_{i,j+1} + T_{i,j-1} + T_{i+1,j} + T_{i-1,j}}{4}$

Top boundary B.C.:  $T_{i,0} = T_0$

Bottom boundary B.C.:  $T_{i,L} = T_1$

**RIGHT BOUNDARY B.C.**

Top boundary:  $T(x,0) = T_0$

Bottom boundary:  $T(x,L) = T_1$

Central difference:  $T_{i,j} = \frac{T_{i,j+1} + T_{i,j-1} + T_{i+1,j} + T_{i-1,j}}{4}$

Right boundary B.C.:  $T_{M,j} = T_1$

**[A] MATRIX:**

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

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

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

**FINITE DIFFERENCE:**

Centered finite-difference approximation:

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

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

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