

# 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 =  $y_i - \hat{y}_i$

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

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

## 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:

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

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

## 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.

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

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

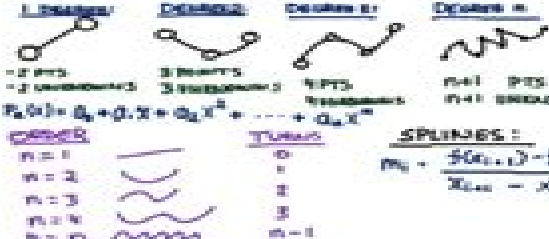
$$\frac{\partial S_r}{\partial a_2} = -2(\sum y_i x_i^2 - \sum a_0 \sum x_i^2 - a_1 \sum x_i^3 - a_2 \sum x_i^4) = 0$$

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

Use Gauss-Jordan elimination.

## 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

$$\frac{dy}{dx} = f(x,y)$$

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

$$y_0 = 1, x_0 = 0$$

$$y_1 = y_0 + \frac{f(x_0, y_0)}{2} \Delta x = 1 + \frac{f(0, 1)}{2} \Delta x$$

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

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

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

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

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

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

## PDE'S

### Finite Difference Method



## EIGEN VALUES

$\lambda = \text{Eigen Value}$

$$\begin{bmatrix} a_{11} - \lambda & a_{12} & a_{13} \\ a_{21} & a_{22} - \lambda & a_{23} \\ a_{31} & a_{32} & a_{33} - \lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

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

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

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

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

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

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

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

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

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

**RIGHT BOUNDARY B.C.**

Top boundary:  $T = T_0$

Bottom boundary:  $T = T_1$

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:  $T_{i,N} = T_0$

Left boundary:  $T_{i,1} = T_1$

**LEFT BOUNDARY B.C.**

Top boundary:  $T = T_0$

Bottom boundary:  $T = T_1$

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

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Left boundary:  $T_{i,1} = T_1$

**TOP BOUNDARY B.C.**

Top boundary:  $T = T_0$

Bottom boundary:  $T = T_1$

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:  $T_{i,N} = T_0$

Left boundary:  $T_{i,1} = T_1$

**BOTTOM BOUNDARY B.C.**

Top boundary:  $T = T_0$

Bottom boundary:  $T = T_1$

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:  $T_{i,N} = T_0$

Left boundary:  $T_{i,1} = T_1$

**RIGHT BOUNDARY B.C.**

Top boundary:  $T = T_0$

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Bottom boundary:  $T = T_1$

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:  $T_{i,N} = T_0$

Left boundary:  $T_{i,1} = T_1$

**[A] MATRIX:**

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

Right:  $-2u_{i,N} + u_{i,N-1} + u_{i,N+1} = -2\Delta x \Delta y$

Left:  $-2u_{i,1} + u_{i,2} + u_{i,0} = -2\Delta x \Delta y$

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

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

**FINITE DIFFERENCE:**

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

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

Backward:  $f(x) = \frac{f(x) - f(x-\Delta x)}{\Delta x}$

**FINITE DIFFERENCE:**

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

Backward:  $f(x) = \frac{f(x) - f(x-\Delta x)}{\Delta x}$

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