

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:

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

STANDARD DEVIATION:

$$S_y = \sqrt{\frac{S_r}{n-1}} \quad S_x = \sqrt{\frac{2(y_2 - \bar{y})^2}{n-1}}$$

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

POLYNOMIAL QUADRATIC REGRESSION:



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

Take derivatives of S_r to find the error.

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

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

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

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

Use Gauss-Jordan elimination to solve for a_0, a_1, a_2 .

INTERPOLATION

Use a polynomial $P(x)$

LAGRANGE	LAGRANGE	LAGRANGE	LAGRANGE
2 pts 1 Lagrange	3 pts 2 Lagrange	4 pts 3 Lagrange	5 pts 4 Lagrange
$P(x) = a_0 + a_1 x$	$P(x) = a_0 + a_1 x + a_2 x^2$	$P(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3$	$P(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4$
Order: 1	Order: 2	Order: 3	Order: 4
Nodes: 2	Nodes: 3	Nodes: 4	Nodes: 5
Nodes: 2	Nodes: 3	Nodes: 4	Nodes: 5
Nodes: 2	Nodes: 3	Nodes: 4	Nodes: 5
Nodes: 2	Nodes: 3	Nodes: 4	Nodes: 5

$$P(x) = \frac{f(x_1)(x-x_2) \dots (x-x_n)}{(x_1-x_2) \dots (x_1-x_n)} + \dots$$

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

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

$$k_1 = f(x_1, y_1)$$

$$k_2 = f(x_1 + \frac{1}{2} \Delta x, y_1 + \frac{1}{2} \Delta x k_1)$$

$$k_3 = f(x_1 + \Delta x, y_1 + \Delta x k_2)$$

$$y_2 = y_1 + \Delta x \frac{k_1 + 2k_2 + k_3}{3}$$

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

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

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

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

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

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

PDE'S

Finite Difference Method



EIGEN VALUES

$\lambda = \text{Eigen Value}$

Example: 2×2

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

The determinant:

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

$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \frac{1}{\det(A)} \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} a-b \\ c-d \end{bmatrix}$$

$$\det(A) = \frac{1}{\det(A)} \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} a-b \\ c-d \end{bmatrix}$$

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

Find Eigen Value with given

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

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

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

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

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

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

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

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

1D Heat Conduction



$$u_{i-1}(t) = u_i(t) - \Delta x u_x(t) = u_i(t) - \frac{u_i(t) - u_{i-1}(t)}{\Delta x} \Delta x$$

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2D Heat Conduction



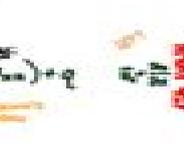
$$u_{i-1,j} = u_{i,j} - \Delta x u_x = u_{i,j} - \frac{u_{i,j} - u_{i-1,j}}{\Delta x} \Delta x$$

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3D Heat Conduction



$$u_{i-1,j,k} = u_{i,j,k} - \Delta x u_x = u_{i,j,k} - \frac{u_{i,j,k} - u_{i-1,j,k}}{\Delta x} \Delta x$$

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1D Heat Conduction



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2D Heat Conduction



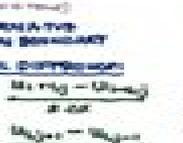
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3D Heat Conduction



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5th Rank of A Matrix



$$\begin{bmatrix} 0 & 1 & 0 & -1 & 1 \\ 1 & 0 & 1 & 0 & -1 \\ 0 & 1 & 0 & -1 & 1 \\ 1 & 0 & 1 & 0 & -1 \\ 0 & 1 & 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$u_{i-1,j} = u_{i,j} - \Delta x u_x = u_{i,j} - \frac{u_{i,j} - u_{i-1,j}}{\Delta x} \Delta x$$

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Left Boundary B.C.



$$u_{i-1}(t) = u_i(t) - \Delta x u_x = u_i(t) - \frac{u_i(t) - u_{i-1}(t)}{\Delta x} \Delta x$$

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TRUNCATION ERROR

Centered Finite-Difference Error

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

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

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E Durkheim



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