

NUMERICAL METHODS

C / KAFFY 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	HERMITE	LAGRANGE	LAGRANGE
2 pts 1 interval 1 degree	3 points 2 intervals 2 degree	4 pts 3 intervals 3 degree	5 pts 4 intervals 4 degree
$P(x) = a_0 + a_1 x + a_2 x^2 + \dots + a_n x^n$			
ORDER		TURNS	SPLINES:
n=1	—	0	$P_1 = \frac{f(x_{i+1}) - f(x_i)}{x_{i+1} - x_i}$
n=2	—	1	
n=3	—	2	
n=4	—	3	
n=5	—	4	

ODE'S

EULER METHOD

$$\frac{dy}{dx} = f(x, y) \quad y_{i+1} = y_i + f(x_i, y_i) \Delta x$$

HEUN'S METHOD

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

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

$$y_{i+1} = y_i + \frac{f(x_i, y_i) + f(x_{i+1}, y_{i+1})}{2} \Delta x$$

Taylor Series:
 $y(x+\Delta x) = y(x) + \Delta x \frac{dy}{dx} + \frac{\Delta x^2}{2} \frac{d^2 y}{dx^2} + \dots$
 $y(x+\Delta x) = y(x) + f(x, y) \Delta x$

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

$\lambda = \text{eigen value}$

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

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

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

$$(a - \lambda)(d - \lambda) - bc = 0$$

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

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

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

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

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

$$x_1 = [-1]$$

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

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

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

$$x_1 = [1]$$

RIGHT BOUNDARY B.C.

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

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

Left boundary: $T(0, y) = T_2$

Right boundary: $T(L, y) = T_3$

Central difference: $T_{i,j} = \frac{T_{i+1,j} + T_{i-1,j} + T_{i,j+1} + T_{i,j-1} - 4T_{i,j}}{4\Delta x^2}$

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

Left boundary B.C.: $T_{0,j} = T_2$

Right boundary B.C.: $T_{M,j} = T_3$

LEFT BOUNDARY B.C.

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

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

Left boundary: $T(0, y) = T_2$

Right boundary: $T(L, y) = T_3$

Central difference: $T_{i,j} = \frac{T_{i+1,j} + T_{i-1,j} + T_{i,j+1} + T_{i,j-1} - 4T_{i,j}}{4\Delta x^2}$

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

Left boundary B.C.: $T_{0,j} = T_2$

Right boundary B.C.: $T_{M,j} = T_3$

TOP BOUNDARY B.C.

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

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

Left boundary: $T(0, y) = T_2$

Right boundary: $T(L, y) = T_3$

Central difference: $T_{i,j} = \frac{T_{i+1,j} + T_{i-1,j} + T_{i,j+1} + T_{i,j-1} - 4T_{i,j}}{4\Delta x^2}$

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

Left boundary B.C.: $T_{0,j} = T_2$

Right boundary B.C.: $T_{M,j} = T_3$

5th ROW OF A MATRIX

Local's finite diff adjacent to boundary

$$\begin{bmatrix} 0 & -1 & 0 & -1 & 4 & -1 & 0 & -1 & 0 \end{bmatrix} \begin{bmatrix} T_{i,j} \\ T_{i,j-1} \\ T_{i,j+1} \\ T_{i,j-2} \\ T_{i,j+2} \\ T_{i,j-3} \\ T_{i,j+3} \\ T_{i,j-4} \\ T_{i,j+4} \end{bmatrix} = 0$$

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

Left boundary B.C.: $T_{0,j} = T_2$

Right boundary B.C.: $T_{M,j} = T_3$

[A] MATRIX:

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

Left boundary B.C.: $T_{0,j} = T_2$

Right boundary B.C.: $T_{M,j} = T_3$

Central difference: $T_{i,j} = \frac{T_{i+1,j} + T_{i-1,j} + T_{i,j+1} + T_{i,j-1} - 4T_{i,j}}{4\Delta x^2}$

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

Left boundary B.C.: $T_{0,j} = T_2$

Right boundary B.C.: $T_{M,j} = T_3$

FINITE DIFFS:

Centered finite-diff second order:

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

Numerical Methods Unit Guide

Christian Drosten



Numerical Methods Unit Guide:

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web based on the dc comics supervillain of the same name he is depicted as a psychopathic criminal mastermind with a warped sadistic sense of humor who defines himself by his conflict with the vigilante batman in the film the joker tests how far batman will go to save gotham city from descending into chaos

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