

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 $P(x)$



$$P(x) = a_0 + a_1 x + a_2 x^2 + \dots + a_n x^n$$



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

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

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

$$y_1 = 1, y_2 = 2$$

$$y_3 = y_2 + \Delta x \left[\frac{f(x_2, y_2) + f(x_3, y_3)}{2} \right]$$

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

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

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

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

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

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

PDE'S

Finite Difference Method



Problem: $T_x = 0$ on $x=0$, $T_x = 0$ on $x=L$, $T = 0$ on $y=0$, $T = 1$ on $y=L$

Central Difference:

$$u_{i,j}(t) = \frac{u_{i+1,j}(t) - u_{i-1,j}(t)}{2\Delta x} + u_{i,j+1}(t) - u_{i,j-1}(t)$$

EIGEN VALUES

Example: $A = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$

$$\det(A - \lambda I) = \det \begin{bmatrix} 1-\lambda & 2 \\ 3 & 4-\lambda \end{bmatrix} = (1-\lambda)(4-\lambda) - 6 = \lambda^2 - 5\lambda - 2 = 0$$

$$\lambda = \frac{5 \pm \sqrt{25 + 8}}{2} = \frac{5 \pm \sqrt{33}}{2}$$

Single 2x2:

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

$$\det(A - \lambda I) = \det \begin{bmatrix} a-\lambda & b \\ c & d-\lambda \end{bmatrix} = (a-\lambda)(d-\lambda) - bc = \lambda^2 - (a+d)\lambda + (ad-bc) = 0$$

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

Find Eigen Vectors:

$$(A - \lambda I) \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

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

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

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

Eigen Vectors: $x_1 = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$

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

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

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

Eigen Vectors: $x_2 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$

[A] MATRIX: $u_{i,j} = 9u_{i,j} - 4u_{i,j-1} - 4u_{i,j+1} - 4u_{i-1,j} - 4u_{i+1,j} = 2\Delta x \Delta y$

Left Boundary B.C.: $-2u_{1,j} = 4u_{1,j} - 4u_{1,j-1} - 4u_{1,j+1} - 4u_{0,j} - 4u_{2,j} = -2\Delta x \Delta y$

Right Boundary B.C.: $-2u_{M,j} = 4u_{M,j} - 4u_{M,j-1} - 4u_{M,j+1} - 4u_{M-1,j} - 4u_{M+1,j} = -2\Delta x \Delta y$

Top Boundary B.C.: $-4u_{i,0} = 4u_{i,0} - 4u_{i,0-1} - 4u_{i,0+1} - 4u_{i-1,0} - 4u_{i+1,0} = -2\Delta x \Delta y$

Bottom Boundary B.C.: $-4u_{i,L} = 4u_{i,L} - 4u_{i,L-1} - 4u_{i,L+1} - 4u_{i-1,L} - 4u_{i+1,L} = -2\Delta x \Delta y$

TRIC CORNER

Centered Finite-Cornered Difference:

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

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

Central Difference



Right Boundary B.C.: $\frac{\partial u}{\partial x} = u_x = \frac{u_{i+1,j} - u_{i-1,j}}{2\Delta x}$

Left Boundary B.C.: $\frac{\partial u}{\partial x} = u_x = \frac{u_{i+1,j} - u_{i-1,j}}{2\Delta x}$

Top Boundary B.C.: $\frac{\partial u}{\partial y} = u_y = \frac{u_{i,j+1} - u_{i,j-1}}{2\Delta y}$

Bottom Boundary B.C.: $\frac{\partial u}{\partial y} = u_y = \frac{u_{i,j+1} - u_{i,j-1}}{2\Delta y}$

5th Row of A Matrix



Right Boundary B.C.: $\frac{\partial u}{\partial x} = u_x = \frac{u_{i+1,j} - u_{i-1,j}}{2\Delta x}$

Left Boundary B.C.: $u_{i-1,j} = u_{i,j} - 2\Delta x u_x$

Numerical Computing With Matlab Solutions

Yan Bai



Numerical Computing With Matlab Solutions :

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