

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.

Residual error: $e_i = y_i - \hat{y}_i$

Sum of squares of residuals: $S = \sum_{i=1}^n e_i^2 = \sum_{i=1}^n (y_i - a_0 - a_1 x_i)^2$

Normal equations:

$$\frac{\partial S}{\partial a_0} = -2 \sum_{i=1}^n (y_i - a_0 - a_1 x_i) = 0$$

$$\frac{\partial S}{\partial a_1} = -2 \sum_{i=1}^n x_i (y_i - a_0 - a_1 x_i) = 0$$

Matrix form: $\begin{bmatrix} n & \sum x_i \\ \sum x_i & \sum x_i^2 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum x_i y_i \end{bmatrix}$

STANDARD ERROR:

$$S_y = \sqrt{\frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{n-2}}$$

$$S_x = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-2}}$$

STANDARD DEVIATION:

$$S_y = \sqrt{\frac{\sum_{i=1}^n y_i^2}{n-1} - \frac{(\sum_{i=1}^n y_i)^2}{n}}$$

$$S_x = \sqrt{\frac{\sum_{i=1}^n x_i^2}{n-1} - \frac{(\sum_{i=1}^n x_i)^2}{n}}$$

INTERPOLATION

Use a 4th order polynomial

Order	Nodes	Degree	Nodes	Degree
1	2	1	3	2
2	3	2	4	3
3	4	3	5	4
4	5	4	6	5

Polynomial form: $P_n(x) = a_0 + a_1 x + a_2 x^2 + \dots + a_n x^n$

Newton's form: $P_n(x) = f(x_0) + f[x_0, x_1](x-x_0) + \dots + f[x_0, \dots, x_n](x-x_0)\dots(x-x_{n-1})$

Lagrange form: $P_n(x) = \sum_{i=0}^n f(x_i) L_i(x)$

Splines: $P_n = \frac{f(x_{i+1}) - f(x_i)}{x_{i+1} - x_i}$

POLYNOMIAL QUADRATIC REGRESSION

Goal: minimize the sum of the squares of the residual errors.

Residual error: $e_i = y_i - \hat{y}_i$

Sum of squares of residuals: $S = \sum_{i=1}^n (y_i - a_0 - a_1 x_i - a_2 x_i^2)^2$

Normal equations:

$$\frac{\partial S}{\partial a_0} = -2 \sum_{i=1}^n (y_i - a_0 - a_1 x_i - a_2 x_i^2) = 0$$

$$\frac{\partial S}{\partial a_1} = -2 \sum_{i=1}^n x_i (y_i - a_0 - a_1 x_i - a_2 x_i^2) = 0$$

$$\frac{\partial S}{\partial a_2} = -2 \sum_{i=1}^n x_i^2 (y_i - a_0 - a_1 x_i - a_2 x_i^2) = 0$$

Matrix form: $\begin{bmatrix} n & \sum x_i & \sum x_i^2 \\ \sum x_i & \sum x_i^2 & \sum x_i^3 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum x_i y_i \\ \sum x_i^2 y_i \end{bmatrix}$

ODE'S

Runge-Kutta method:

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

Heun's method:

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

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

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

$k_1 = f(x_i, y_i)$
 $k_2 = f(x_i + \frac{1}{2}\Delta x, y_i + \frac{1}{2}\Delta x k_1)$
 $k_3 = f(x_i + \frac{1}{2}\Delta x, y_i + \Delta x k_2)$
 $k_4 = f(x_i + \Delta x, y_i + \Delta x k_3)$

Local truncation error: $\propto \Delta x^5$

Global truncation error: $\propto \Delta x^4$

PDE'S

FINITE DIFFERENCE METHOD

Central difference:

$$\frac{\partial^2 u}{\partial x^2} \approx \frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta x^2}$$

Forward difference:

$$\frac{\partial u}{\partial x} \approx \frac{u_i - u_{i-1}}{\Delta x}$$

Backward difference:

$$\frac{\partial u}{\partial x} \approx \frac{u_{i+1} - u_i}{\Delta x}$$

Stability: $\Delta t \leq \frac{\Delta x^2}{2D}$

EIGEN VALUES

Single 2x2:

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

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

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

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

3x3 MATRIX

Characteristic equation:

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

Eigenvalues: $\lambda_1, \lambda_2, \lambda_3$

Eigenvectors: x_1, x_2, x_3

[A] MATRIX

Central difference:

$$u_{i,j} - 2u_{i,j} + u_{i+1,j} + u_{i-1,j} = -2\Delta x^2 \frac{\partial^2 u}{\partial x^2}$$

Forward difference:

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

Backward difference:

$$u_{i,j} - u_{i+1,j} = -\Delta x \frac{\partial u}{\partial x}$$

RIGHT BOUNDARY B.C.

$$\frac{\partial u}{\partial x} = 0 \Rightarrow u_{i,j} = u_{i+1,j}$$

LEFT BOUNDARY B.C.

$$\frac{\partial u}{\partial x} = 0 \Rightarrow u_{i,j} = u_{i-1,j}$$

TOP BOUNDARY B.C.

$$u_{i,0} = 0$$

BOTTOM BOUNDARY B.C.

$$u_{i,N} = 0$$

TRUNCATION ERROR

Centered finite-difference error:

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

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

Numerical Analysis Using R

Lingjun Ying



Numerical Analysis Using R:

Decoding **Numerical Analysis Using R**: Revealing the Captivating Potential of Verbal Expression

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