

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 derivative 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

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

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

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

$$y_{i+1} = y_i + \frac{f(x_i, y_i) + f(x_{i+1}, y_i) + f(x_i, y_{i+1}) + f(x_{i+1}, y_{i+1})}{4} \Delta x$$

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

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

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

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

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

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

PDE'S

Finite Difference Method



EIGEN VALUES

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

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

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

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

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

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

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

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

$$(a-\lambda)x_1 + bx_2 = 0$$

$$cx_1 + (d-\lambda)x_2 = 0$$

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

$$-ax_1 + bx_2 = 0 \quad x_2 = \frac{a}{b}x_1$$

$$cx_1 - dx_2 = 0 \quad x_2 = \frac{c}{d}x_1$$

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

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

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

RIGHT BOUNDARY B.C.

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

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

[A] MATRIX:

$$-2u_{i,j} + u_{i-1,j} + u_{i+1,j} + u_{i,j-1} + u_{i,j+1} = 2\Delta x \Delta y T_0$$

$$-2u_{i,j} + u_{i-1,j} + u_{i+1,j} + u_{i,j-1} + u_{i,j+1} = -2\Delta x \Delta y T_1$$

$$-2u_{i,j} + u_{i-1,j} + u_{i+1,j} + u_{i,j-1} + u_{i,j+1} = -2\Delta x \Delta y T_2$$

$$-2u_{i,j} + u_{i-1,j} + u_{i+1,j} + u_{i,j-1} + u_{i,j+1} = -2\Delta x \Delta y T_3$$

FINITE DIFFERENCE:

Centered finite-difference approximation:

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

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

Numerical Analysis Using R

Victor M. Corman



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