

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.



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

1. sum of the square errors.
2. minimize the square of the errors.

$$a_0 = \frac{\sum y_i - a_1 \sum x_i}{n}$$

$$a_0 = \frac{\sum y_i}{n} - a_1 \frac{\sum x_i}{n} \Rightarrow a_0 = 5 - 0.8$$

STANDARD ERROR:

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

STANDARD DEVIATION:

$$S_y = \sqrt{\frac{\sum y_i}{n-1}} \quad S_x = \sqrt{\frac{\sum (y_i - y)^2}{n-1}}$$

$$a_0 = 5 - 0.8x$$

$$3 = 0.8 + 0.8x$$

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.

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

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

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

$$\begin{bmatrix} \sum 1 & \sum x_i & \sum x_i^2 \\ \sum x_i & \sum x_i^2 & \sum x_i^3 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum y_i x_i \\ \sum y_i x_i^2 \end{bmatrix} \rightarrow [A][X] = [B]$$

$S_y = \sqrt{\frac{\sum y_i^2}{n}}$
COEFFICIENT OF DETERMINATION
 $r^2 = \frac{S_y^2 - S_{y_1}^2}{S_y^2}$

PDE'S

FINITE DIFFERENCE METHOD:



PROBLEM 1:
T is 2D rectangular
T is 2D square
L = R
S = 0°C
T is 2D rectangular
L = 1
R = 1
S = 20°C
T is 2D square
L = 1
R = 1
S = 20°C
CENTRAL DIFFERENCE
 $u_{i,j}(t) = \frac{u_{i-1,j} + u_{i+1,j} + u_{i,j-1} + u_{i,j+1}}{4}$
 $u_{0,j}(t) = u_{i,0}(t) = u_{i,j-1}(t) = u_{i,j+1}(t) = 0$

EIGEN VALUES

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

Single 2x2:
 $A = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} \lambda x \\ \lambda y \end{bmatrix}$
 $\Delta(x) = \det(A - \lambda I) = \det \begin{bmatrix} a-\lambda & b \\ c & d-\lambda \end{bmatrix}$
 $\Delta(x) = (a-\lambda)(d-\lambda) - bc = \lambda^2 - (a+d)\lambda + (ad-bc)$
 $\lambda = \frac{-(a+d) \pm \sqrt{(a+d)^2 - 4(ad-bc)}}{2}$

Two eigen values with same
 $\begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} \lambda x_1 \\ \lambda x_2 \end{bmatrix}$
 $\begin{cases} (a-\lambda)x_1 + bx_2 = 0 \\ cx_1 + (d-\lambda)x_2 = 0 \end{cases}$
 $\lambda_1 = \lambda_2 = \lambda$
 $x_1 = -x_2$
 $x_1 = -x_2$
 $x_1 = x_2$
 $x_1 = -x_2$
 $x_1 = x_2$
 $\Delta(x) = \begin{bmatrix} a-\lambda & b \\ c & d-\lambda \end{bmatrix}$

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

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

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

LEFT BOUNDARY B.C.
 $u_{i-1,j} = u_{i,j} - 2\Delta x u_x$

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

TRICK EQUATION:
CENTERED FINITE-DIFFERENCE EQUATION:
FIRST: $f(x) = \frac{f(x_0) - f(x_1)}{2\Delta x}$
 $f(x) = \frac{f(x_0) - 3f(x_1) + 3f(x_2) - f(x_3)}{12\Delta x}$

INTERPOLATION

USE 2 POINTS: LINEAR
USE 3 POINTS: QUADRATIC
USE 4 POINTS: CUBIC
USE 5 POINTS: QUARTIC

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

ORDER: $n=1$ (line), $n=2$ (parabola), $n=3$ (cubic), $n=4$ (quartic)

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

TAYLOR SERIES:
 $y(x) = y_0 + y_0' x + \frac{y_0''}{2!} x^2 + \dots$
 $y(x) = y_0 + f(x_0) \Delta x$

ODE'S

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

ROMBERG METHOD:
 $y' = \frac{y^2 + 2x}{2} = f(x, y) = f(x_0, y_0) + f(x_1, y_1) + \dots$

CLASSIC 4th ORDER RUNGE-KUTTA:
 $y_{i+1} = y_i + \frac{\Delta x}{4} (k_1 + 3k_2 + 3k_3 + k_4)$
 $k_1 = f(x_i, y_i)$
 $k_2 = f(x_i + \frac{1}{2}\Delta x, y_i + \frac{1}{2}k_1 \Delta x)$
 $k_3 = f(x_i + \frac{1}{2}\Delta x, y_i + \frac{1}{2}k_2 \Delta x)$
 $k_4 = f(x_i + \Delta x, y_i + k_3 \Delta x)$

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