

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 derivatives of S_r to find the error.

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

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

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

$$\begin{bmatrix} \sum 1 & \sum x_i & \sum x_i^2 \\ \sum x_i & \sum x_i^2 & \sum x_i^3 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum y_i x_i \\ \sum y_i x_i^2 \end{bmatrix}$$

Use Gauss-Jordan elimination.

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 | |
| n=1 | — | 0 | |
| n=2 | — | 1 | |
| n=3 | — | 2 | |
| n=4 | — | 3 | |
| n=5 | — | 4 | |

$$P(x) = \frac{f(x_1)(x-x_2)\dots(x-x_n) + \dots + f(x_n)(x-x_1)\dots(x-x_{n-1})}{(x-x_2)\dots(x-x_n) + \dots + (x-x_1)\dots(x-x_{n-1})}$$

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

CLASSIC 4th ORDER RUNGE-KUTTA

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

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

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

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

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

EIGEN VALUES

$\lambda = \text{eigen value}$

Example:

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

TRICKS:

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

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

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

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

Find eigen with page

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

$$\begin{cases} (a-\lambda)x_1 + bx_2 = 0 \\ cx_1 + (d-\lambda)x_2 = 0 \end{cases}$$

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

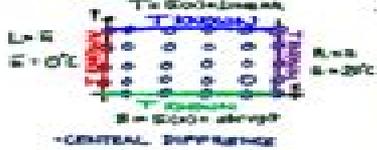
$$\begin{cases} -ax_1 + bx_2 = 0 \\ cx_1 - dx_2 = 0 \end{cases}$$

PDE'S

FINITE DIFFERENCE METHOD:



PROBLEM 1:



$$u_{i,j}(x) = u(x_j - \Delta x, y_i) - 2u(x_j, y_i) + u(x_j + \Delta x, y_i)$$

$$u_{i,j}(y) = u(x_j, y_i - \Delta y) - 2u(x_j, y_i) + u(x_j, y_i + \Delta y)$$

BC (Boundary Conditions):

Top boundary: $u_{i,j} = 0$
 Bottom boundary: $u_{i,j} = 1$
 Left boundary: $u_{i,0} = 0$
 Right boundary: $u_{i,N} = 0$

INTERNAL:



RIGHT NEIGHBOR B.C.
 $\frac{\partial u}{\partial x} = 0 = \frac{u_{i,j+1} - u_{i,j-1}}{2\Delta x}$
 $u_{i,j+1} = u_{i,j-1} + 2\Delta x \frac{\partial u}{\partial x}$

BOTTOM NEIGHBOR B.C.
 $\frac{\partial u}{\partial y} = 0 = \frac{u_{i,j} - u_{i,j+1}}{2\Delta y}$
 $u_{i,j} = u_{i,j+1} - 2\Delta y \frac{\partial u}{\partial y}$

TOP NEIGHBOR B.C.
 $\frac{\partial u}{\partial y} = 0 = \frac{u_{i,j} - u_{i,j-1}}{2\Delta y}$
 $u_{i,j} = u_{i,j-1} + 2\Delta y \frac{\partial u}{\partial y}$

LEFT NEIGHBOR B.C.
 $u_{i,j} = u_{i,j-1} - 2\Delta x \frac{\partial u}{\partial x}$

[A] MATRIX:

$$-u_{i-1,j} + 4u_{i,j} - u_{i+1,j} - u_{i,j-1} = 2\Delta x \frac{\partial u}{\partial x}$$

$$-2u_{i,j} + 4u_{i,j} - u_{i,j-1} - u_{i,j+1} = -2\Delta x \frac{\partial u}{\partial x}$$

$$-2u_{i,j} + 4u_{i,j} - u_{i,j-1} - u_{i,j+1} = -2\Delta x \frac{\partial u}{\partial x}$$

$$-u_{i,j} - u_{i,j+1} + 4u_{i,j} - 2u_{i,j-1} = -2\Delta x \frac{\partial u}{\partial x}$$

$$-u_{i,j} - u_{i,j-1} + 4u_{i,j} - 2u_{i,j+1} = -2\Delta x \frac{\partial u}{\partial x}$$

TRICKS:

CENTERED FINITE-DIFFERENCE DERIVATIVE:
 $f'(x) = \frac{f(x+\Delta x) - f(x-\Delta x)}{2\Delta x}$
 $f''(x) = \frac{f(x-\Delta x) - 2f(x) + f(x+\Delta x))}{\Delta x^2}$

Numerical Analysis Using R

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