

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 the error.

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

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

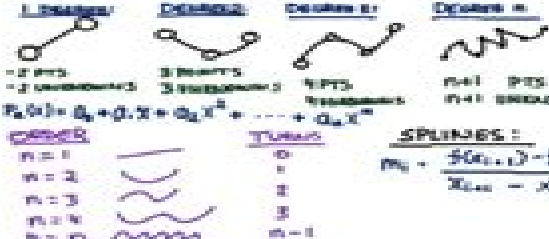
$$\frac{\partial S_r}{\partial a_2} = -2 \left(\sum y_i x_i^2 - \sum a_0 x_i^2 - a_1 \sum x_i^3 - a_2 \sum x_i^4 \right) = 0$$

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

Use Gauss-Jordan elimination.

INTERPOLATION

Use a polynomial $P(x)$



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

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

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

$$y_0 = 1, x_0 = 0$$

$$y_1 = y_0 + \frac{f(x_0, y_0)}{2} \Delta x = 1 + \frac{f(0, 1)}{2} \Delta x$$

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

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

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

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

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

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

PDE'S

Finite Difference Method



EIGEN VALUES

$\lambda = \text{Eigen Value}$

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

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

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

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

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

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

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

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

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

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

RIGHT BOUNDARY BC

Top boundary: $T = T_{top}$

Bottom boundary: $T = T_{bottom}$

Central difference: $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

Right boundary BC: $\frac{\partial T}{\partial x} = 0 \Rightarrow \frac{T_{i+1} - T_{i-1}}{2\Delta x} = 0 \Rightarrow T_{i+1} = T_{i-1}$

LEFT BOUNDARY BC

Top boundary: $T = T_{top}$

Bottom boundary: $T = T_{bottom}$

Central difference: $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

Left boundary BC: $\frac{\partial T}{\partial x} = 0 \Rightarrow \frac{T_{i+1} - T_{i-1}}{2\Delta x} = 0 \Rightarrow T_{i+1} = T_{i-1}$

TOP BOUNDARY BC

Central difference: $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

Top boundary BC: $T = T_{top}$

RIGHT BOUNDARY BC

Central difference: $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

Right boundary BC: $\frac{\partial T}{\partial x} = 0 \Rightarrow \frac{T_{i+1} - T_{i-1}}{2\Delta x} = 0 \Rightarrow T_{i+1} = T_{i-1}$

5th Row of A Matrix

Central difference: $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

Boundary conditions: $T = T_{top}$ and $T = T_{bottom}$

[A] MATRIX:

Central difference: $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

Boundary conditions: $T = T_{top}$ and $T = T_{bottom}$

FINITE DIFFERENCE:

Central difference: $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

Boundary conditions: $T = T_{top}$ and $T = T_{bottom}$

Numerical Analysis Using R

Ensheng Dong



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