

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 $d_i = y_i - \hat{y}_i$
 $a_0 = \frac{\sum y_i - a_1 \sum x_i}{n}$
 $a_1 = \frac{\sum x_i y_i - \frac{(\sum x_i)(\sum y_i)}{n}}{\sum x_i^2 - \frac{(\sum x_i)^2}{n}}$

Example: $a_0 = 5 - 0.8$

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.

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

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

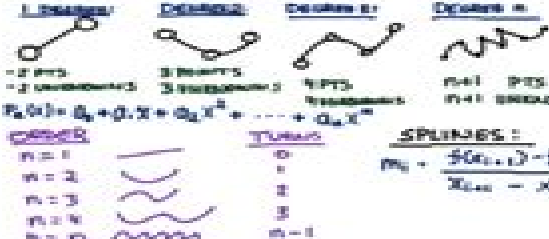
$$\frac{\partial S_r}{\partial a_2} = -2(\sum x_i^2 y_i - \sum a_0 \sum x_i^2 - a_1 \sum x_i^3 - a_2 \sum x_i^4) = 0$$

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

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

$$y' = f(x,y)$$

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

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

$$k_3 = f(x_i + \Delta x, y_i + \Delta x k_2)$$

$$y_{i+1} = y_i + \Delta x \frac{k_1 + 2k_2 + k_3}{3}$$

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

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

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

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

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

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

PDE'S

Finite Difference Method



EIGEN VALUES

$\lambda = \text{Eigen Value}$

Example:

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

The solution:

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

Single 2x2:

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

$$\Delta = \det(A) = \det \begin{bmatrix} a-\lambda & b \\ c & d-\lambda \end{bmatrix} = (a-\lambda)(d-\lambda) - bc = \lambda^2 - (a+d)\lambda + (ad-bc)$$

Two eigen values:

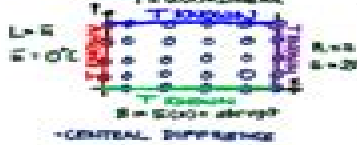
$$\begin{bmatrix} a-\lambda_1 & b \\ c & d-\lambda_1 \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$x_1 = \begin{bmatrix} - \\ \end{bmatrix}$$

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

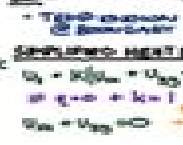
$$\begin{bmatrix} -\lambda_1 + 1 & 1 \\ 1 & -\lambda_1 + 1 \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

1D Heat Conduction



$$u_{i+1}(t) = u_i(t) - \alpha \Delta x (u_{i+1} - u_i) - \alpha \Delta x (u_i - u_{i-1})$$

2D Heat Conduction



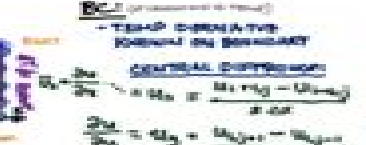
$$u_{i,j}(t) = u_{i,j}(t) - \alpha \Delta x^2 (u_{i+1,j} + u_{i-1,j} + u_{i,j+1} + u_{i,j-1} - 4u_{i,j})$$

1D Advection



$$u_{i+1}(t) = u_i(t) - \frac{u_{i+1} - u_i}{\Delta x} \Delta x \Delta t$$

2D Advection



$$u_{i,j}(t) = u_{i,j}(t) - \frac{u_{i+1,j} - u_{i,j}}{\Delta x} \Delta x \Delta t - \frac{u_{i,j+1} - u_{i,j}}{\Delta y} \Delta y \Delta t$$

5th Rank of a Matrix



$$[\begin{matrix} 0 & -1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{matrix}] \begin{bmatrix} x \\ y \\ z \\ w \\ v \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

[A] MATRIX:

$$-2u_{i,j} + 4u_{i,j} - u_{i,j} - u_{i,j} = -2 \Delta x \bar{u}_i$$

$$-2u_{i,j} + 4u_{i,j} - u_{i,j} - u_{i,j} = -2 \Delta x \bar{u}_i$$

$$-2u_{i,j} + 4u_{i,j} - u_{i,j} - u_{i,j} = -2 \Delta x \bar{u}_i$$

$$-2u_{i,j} + 4u_{i,j} - u_{i,j} - u_{i,j} = -2 \Delta x \bar{u}_i$$

5th Rank:

$$f(x) = \frac{f(x) - f(x-1)}{\Delta x}$$

$$f(x) = \frac{f(x) - 3f(x-1) + 3f(x-2) - f(x-3)}{12 \Delta x}$$

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