

# NUMERICAL METHODS

C / RAPPY EXAM 12 / 11/19 / 2022 [20.000]

## LEAST SQUARES REGRESSION

GOAL: MINIMIZE THE SUM OF THE SQUARES OF THE RESIDUALS (ERRORS)

RESIDUAL:  $y_i - \hat{y}_i$

MINIMIZATION:  $S = \sum (y_i - a_0 - a_1 x_i)^2$

FORMULAS:

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

$$a_1 = \frac{\sum x_i y_i - \frac{(\sum x_i)(\sum y_i)}{n}}{\sum x_i^2 - \frac{(\sum x_i)^2}{n}}$$

## STANDARD ERROR:

$$S_y = \sqrt{\frac{\sum (y_i - \hat{y}_i)^2}{n-2}}$$

$$S_x = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-2}}$$

## STANDARD DEVIATION:

$$S_y = \sqrt{\frac{\sum y_i^2}{n-1}}$$

$$S_x = \sqrt{\frac{\sum x_i^2}{n-1}}$$

## POLYNOMIAL QUADRATIC REGRESSION:

GOAL: FIND COEFFICIENTS  $a_0, a_1, a_2$  TO MINIMIZE ERROR

MINIMIZATION:  $S = \sum (y_i - a_0 - a_1 x_i - a_2 x_i^2)^2$

FORMULAS:

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

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

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

COEFFICIENT OF DETERMINATION:  $R^2 = \frac{S_{yy} - \frac{(\sum y_i)^2}{n}}{S_{yy}}$

## INTERPOLATION

USE 2 POINTS: LINEAR

USE 3 POINTS: QUADRATIC

USE 4 POINTS: CUBIC

USE 5 POINTS: QUARTIC

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

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

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

## ODE'S

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

HEUN'S METHOD:  $y_{i+1} = y_i + f(x_i, y_i) \Delta x + \frac{f(x_{i+1}, y_{i+1}) - f(x_i, y_i)}{2} \Delta x^2$

FORMULAS:

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

$$y' = \frac{y^2 + 2x}{2}$$

$$y' = \frac{y^2 + 2x}{2} = f(x, y) = f(x_0, y_0) + f'(x_0, y_0) \Delta x + \dots$$

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

## CLASSIC 4th ORDER RUNGE-KUTTA:

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

DEFINITIONS:

- $k_1 = f(x_i, y_i)$
- $k_2 = f(x_i + \frac{1}{2}\Delta x, y_i + \frac{1}{2}k_1 \Delta x)$
- $k_3 = f(x_i + \frac{1}{2}\Delta x, y_i + k_2 \Delta x)$
- $k_4 = f(x_i + \Delta x, y_i + k_3 \Delta x)$

TRUNCATION ERROR:  $\Delta y_i = \Delta x \int_{x_i}^{x_{i+1}} R_4(x) dx$

STABILITY:  $y_{i+1} = y_i + \Delta x \int_{x_i}^{x_{i+1}} R_4(x) dx$

## EIGEN VALUES

1. EIGEN VALUE

2x2 MATRIX:  $A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$

CHARACTERISTIC EQUATION:  $\det(A - \lambda I) = 0$

$$(a-\lambda)(d-\lambda) - bc = 0$$

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

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

EIGEN VECTORS:  $(A - \lambda I)v = 0$

## PDE'S

FINITE DIFFERENCE METHOD:

1D HEAT CONDUCTION:

GOVERNING EQUATION:  $\frac{\partial^2 T}{\partial x^2} = 0$

BOUNDARY CONDITIONS:

- LEFT:  $T(x=0) = T_0$
- RIGHT:  $T(x=L) = T_L$

CENTRAL DIFFERENCE:  $T_{i+1} - 2T_i + T_{i-1} = 0$

FORMULAS:

$$T_{i+1} = 2T_i - T_{i-1}$$

$$T_{i-1} = 2T_i - T_{i+1}$$

## HEAT CONDUCTION

1D HEAT CONDUCTION:

GOVERNING EQUATION:  $\frac{\partial^2 T}{\partial x^2} = 0$

BOUNDARY CONDITIONS:

- LEFT:  $T(x=0) = T_0$
- RIGHT:  $T(x=L) = T_L$

CENTRAL DIFFERENCE:  $T_{i+1} - 2T_i + T_{i-1} = 0$

FORMULAS:

$$T_{i+1} = 2T_i - T_{i-1}$$

$$T_{i-1} = 2T_i - T_{i+1}$$

[A] MATRIX:

1D HEAT CONDUCTION:

GOVERNING EQUATION:  $\frac{\partial^2 T}{\partial x^2} = 0$

BOUNDARY CONDITIONS:

- LEFT:  $T(x=0) = T_0$
- RIGHT:  $T(x=L) = T_L$

CENTRAL DIFFERENCE:  $T_{i+1} - 2T_i + T_{i-1} = 0$

FORMULAS:

$$T_{i+1} = 2T_i - T_{i-1}$$

$$T_{i-1} = 2T_i - T_{i+1}$$

## TRUNCATION ERROR

TRUNCATION ERROR:

FORMULA:  $\tau = \frac{f''(\xi)}{2!}(\Delta x)^2$

FORMULAS:

$$f(x) = f(x_0) + f'(x_0)\Delta x + \frac{f''(\xi)}{2!}(\Delta x)^2 + \dots$$

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