

# NUMERICAL METHODS

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

## LEAST SQUARES REGRESSION



$a_0 = \frac{\sum y_i}{n} - a_1 \bar{x}$   
 $a_1 = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2}$

## POLYNOMIAL QUADRATIC REGRESSION:



$S_0 = \sum (y_i - a_0 - a_1 x_i - a_2 x_i^2)^2$   
 $\frac{\partial S_0}{\partial a_0} = -2(\sum y_i - \sum a_0 - a_1 \sum x_i - a_2 \sum x_i^2) = 0$   
 $\frac{\partial S_0}{\partial a_1} = -2(\sum x_i y_i - \sum a_0 \sum x_i - a_1 \sum x_i^2 - a_2 \sum x_i^3) = 0$   
 $\frac{\partial S_0}{\partial a_2} = -2(\sum x_i^2 y_i - \sum a_0 \sum x_i^2 - a_1 \sum x_i^3 - a_2 \sum x_i^4) = 0$

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

## STANDARD ERROR:

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

## STANDARD DEVIATION:

$S_y = \sqrt{\frac{\sum y_i^2}{n-1}}$      $S_x = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$

$a_0 = \bar{y} - a_1 \bar{x}$   
 $a_1 = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2}$

## INTERPOLATION



## ODE'S

**Euler's Method:**  
 $y_{n+1} = y_n + f(x_n, y_n) \Delta x$

## Runge-Kutta Method:

$y_{n+1} = y_n + f(x_n, y_n) \Delta x$   
 $y_{n+1} = y_n + \frac{\Delta x}{2} [f(x_n, y_n) + f(x_n + \Delta x, y_n + \Delta x f(x_n, y_n))]$

**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:

$y_{n+1} = y_n + \frac{\Delta x}{4} (k_1 + 2k_2 + 2k_3 + k_4)$   
 $k_1 = f(x_n, y_n)$   
 $k_2 = f(x_n + \frac{1}{2}\Delta x, y_n + \frac{1}{2}\Delta x k_1)$   
 $k_3 = f(x_n + \frac{1}{2}\Delta x, y_n + \Delta x k_2)$   
 $k_4 = f(x_n + \Delta x, y_n + \Delta x k_3)$

## PDE'S

### FINITE DIFFERENCE METHOD:



## EIGEN VALUES

$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$   
 $\det(A - \lambda I) = 0$   
 $(a-\lambda)(d-\lambda) - bc = 0$   
 $\lambda^2 - (a+d)\lambda + (ad-bc) = 0$

**Single 2x2:**  
 $A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$   
 $\det(A - \lambda I) = 0$   
 $\lambda = \frac{a+d \pm \sqrt{(a-d)^2 + 4bc}}{2}$

**2x2 matrix with zero:**  
 $\begin{bmatrix} a & b \\ 0 & d \end{bmatrix}$   
 $\lambda_1 = a, \lambda_2 = d$

$\begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$   
 $-bx + dy = 0 \Rightarrow y = \frac{b}{d}x$   
 $(x, -bx/d)$

**1D Heat Conduction:**  
 $T_x = 0$   
 $T = 0$   
 $\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}$   
**Central Difference:**  
 $T_{i,j+1} = \alpha \Delta t (T_{i,j-1} - 2T_{i,j} + T_{i,j+1}) + T_{i,j}$

**2D Heat Conduction:**  
 $T_x = 0, T_y = 0$   
 $T = 0$   
 $\frac{\partial T}{\partial t} = \alpha (\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2})$   
**Central Difference:**  
 $T_{i,j,k+1} = \alpha \Delta t (T_{i,j-1,k} + T_{i,j+1,k} + T_{i,j,k-1} + T_{i,j,k+1}) + T_{i,j,k}$

**Right Boundary B.C.:**  
 $\frac{\partial T}{\partial x} = 0 \Rightarrow \frac{T_{i,j+1} - T_{i,j-1}}{2\Delta x} = 0$   
 $T_{i,j+1} = T_{i,j-1}$

**5th Row of A Matrix:**  
 $[0 \ -1 \ 0 \ -1 \ 4 \ -1 \ 0 \ -1 \ 0] [T] = 0$

**[A] MATRIX:**  
 $9u_{i,j} - u_{i,j-1} - u_{i,j+1} - u_{i-1,j} - u_{i+1,j} = 2\Delta x \Delta y$   
 $-2u_{i,j} + 9u_{i,j} - u_{i,j-1} - u_{i,j+1} = -2\Delta x \Delta y$   
 $-u_{i-1,j} - u_{i+1,j} + 9u_{i,j} - 2u_{i,j-1} = -2\Delta x \Delta y$   
 $-u_{i-1,j} - u_{i+1,j} + 9u_{i,j} - 2u_{i,j+1} = -2\Delta x \Delta y$

**TRUNCATION ERROR:**  
**Centered Finite-Difference Error:**  
 $f(x) = \frac{f(x+\Delta x) - f(x-\Delta x)}{2\Delta x}$   
 $f(x) = \frac{f(x+\Delta x) + 3f(x) - 3f(x-\Delta x) + f(x)}{4\Delta x}$

# Guide To Numerical Analysis

**R Sandford**



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