NUMERICAL METHODS

LEAST SQUARES REGRESSION (LINE):
GOAL: MINIMIZE THE SUM OF THE SQUARE OF THE RESIDUAL ERRORS

$$S_r = \sum e_i^2 = \sum (z_i - a_0 - a_1 x_i)^2$$

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

$$a_0 = \frac{\sum y_i}{n} \qquad a_1 = \frac{\sum x_i}{n} \Rightarrow a_0 = \bar{y} - a_1 \bar{x}$$

MEAN:
$$a_0 = \bar{y} - a_1 x$$
$$y = a_0 + a_1 x$$

POLYNOMIAL (QUADRATIC) REGRESSION:

$$S_r = \sum (y_i - a_0 - a_1 x_i - a_2 x_i^2)^2$$

TAKE DERIVATIVE OF S_r FOR EACH PARAMETER:

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

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

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

$$\sum a_i = a_0 n$$

$$[A][X] = [B]$$

$$X = A\backslash B$$

$$S_{y/x} = \sqrt{\frac{S_r}{n-2}}$$

COEFFICIENT OF DETERMINATION:
$$r^2 = \frac{S_t - S_r}{S_t}$$

STANDARD ERROR:
$$S_y = \sqrt{\frac{S_t}{n-1}} \qquad S_{y/x} = \sqrt{\frac{\sum(y_i - y^*)^2}{n-2}}$$

STAND. DEVIATION:
$$S_y = \sqrt{\frac{S_t}{n-1}} \qquad S_y = \sqrt{\frac{\sum(y_i - \bar{y})^2}{n-1}}$$

INTERPOLATION
USE A POLYNOMIAL FIT:

DEGREE 1	DEGREE 2	DEGREE 3	DEGREE n
2 PTS	3 PTS	4 PTS	n+1 PTS

$$P_n(x) = a_0 + a_1 x + a_2 x^2 + \cdots + a_n x^n$$

ORDER | TURNS
n = 1 | 0
n = 2 | 1
n = 3 | 2
n = 4 | 3
n = n | n-1

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

ODE'S
EULER'S METHOD:
$$\frac{dy}{dx} = f(x,y) \qquad y_{i+1} = y_i + f(x_i, y_i)h$$

HEUN'S METHOD:
$$\frac{dy}{dx} = f(x,y)$$
$$x_{i+1} = y_i + f(x_i, y_i)h \quad \text{(PREDICTOR)}$$
$$\frac{dy}{dx} = y_i' = f(x_i, y_i)$$
$$\frac{dy}{dx} = y_i' = f(x_i, y_i)$$
$$y' = \frac{y_i' + y_{i+1}'}{2} = \frac{f(x_i, y_i) + f(x_{i+1}, y_{i+1}^*)}{2}$$
$$y_{i+1} = y_i + \frac{f(x_i, y_i) + f(x_{i+1}, y_{i+1}^*)}{2}\Delta x \quad \text{(CORRECTOR)}$$

TAYLOR SERIES:
$$y(x + \Delta x) = y(x) + \frac{dy}{dx}(x_0)\Delta x$$
$$y(x + \Delta x) = y(x) + f(x,y)\Delta x$$

CLASSIC 4TH ORDER RUNGE-KUTTA:
$$y_{i+1} = y_i + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)\Delta x$$
$$k_1 = f(x_i, y_i)$$
$$k_2 = f(x_i + \tfrac{1}{2}\Delta x, y_i + \tfrac{1}{2}k_1 \Delta x)$$
$$k_3 = f(x_i + \tfrac{1}{2}\Delta x, y_i + \tfrac{1}{2}k_2 \Delta x)$$
$$k_4 = f(x_i + \Delta x, y_i + k_3 \Delta x)$$

DORMAND PRINCE RUNGE-KUTTA:
$$y_{i+1} = y_i + \Delta x \sum_{i=1}^{7} a_i k_i$$
$$y_{i+1} = y_i + \Delta x \sum_{i=1}^{7} a_i k_i$$

EIGEN VALUES
$$\lambda = \text{EIGEN VALUE}$$

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

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

SINGLE 2x2:
$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}^{-1} = \frac{1}{\det(A)}\begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

$$[A]^{-1} = \frac{1}{\det(A)}\begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

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

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

PDE'S
FINITE DIFFERENCE METHOD:

TEMPERATURE

DIRICHLET:
$T =$ BOUNDARY

$L = 6$
$S = 0°C$

BC:
- TEMP KNOWN @ BOUNDARY

DAMPED HEAT EQN:
$$u_t = k(u_{xx} + u_{yy}) + q$$

CENTRAL DIFFERENCE:
$$u_{xx}(x,y) = \frac{u(x - \Delta x, y) - 2u(x,y) + u(x + \Delta x, y)}{\Delta x^2}$$

$$u_{yy}(x,y) = \frac{u(x, y - \Delta y) - 2u(x,y) + u(x, y + \Delta y)}{\Delta y^2}$$

NEUMANN:
BC:
- TEMP DERIVATIVE KNOWN ON BOUNDARY

CENTRAL DIFFERENCE:
$$\frac{\partial u}{\partial x} = q_x = \frac{u_{i+1,j} - u_{i-1,j}}{2\Delta x}$$
$$\frac{\partial u}{\partial y} = q_y = \frac{u_{i,j+1} - u_{i,j-1}}{2\Delta y}$$

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

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

TOP NEUMANN BC:
$$\frac{\partial u}{\partial y} = q_y = \frac{u_{i,j+1} - u_{i,j-1}}{2\Delta y}$$
$$u_{i,j+1} = u_{i,j-1} + 2\Delta y q_y$$

LEFT NEUMANN B.C.:
$$u_{i-1,j} = u_{i+1,j} - 2\Delta x q_x$$

[A] MATRIX:
LEFT:
$$-2u_{i-1,j} + 4u_{i,j} - u_{i,j-1} - u_{i,j+1} = -2\Delta x q_x$$
THIS CHANGED

RIGHT:
$$-2u_{i+1,j} + 4u_{i,j} - u_{i,j-1} - u_{i,j+1} = -2\Delta x q_x$$
THIS CHANGED

BOTTOM:
$$-2u_{i-1,j} - u_{i+1,j} + 4u_{i,j} - 2u_{i,j+1} = -2\Delta x q_y$$
THIS CHANGED

TOP:
$$-u_{i-1,j} - u_{i+1,j} + 4u_{i,j} - 2u_{i,j-1} = -2\Delta x q_y$$
THIS CHANGED

MISC EQN'S:
CENTERED FINITE DIVIDED DIFF FORMULA:
FIRST:
$$f'(x_i) = \frac{f(x_{i+1}) - f(x_{i-1})}{2h}$$
$$f'(x_i) = \frac{-f(x_{i+2}) + 8f(x_{i+1}) - 8f(x_{i-1}) + f(x_{i-2})}{12h}$$

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Won Y. Yang,Wenwu Cao,Jaekwon Kim,Kyung W. Park,Ho-Hyun Park,Jingon Joung,Jong-Suk Ro,Han L. Lee,Cheol-Ho Hong,Taeho Im

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and engineers thus have a crucial means of using numerical results to modify and adapt arguments and experiments along the way Every facet of technical and industrial activity has been affected by these developments The objective of the present work is to compile the mathematical knowledge required by researchers in mechanics physics engineering chemistry and other branches of application of mathematics for the theoretical and numerical resolution of physical models on computers Since the publication in 1924 of the Methoden der mathematischen Physik by Courant and Hilbert there has been no other comprehensive and up to date publication presenting the mathematical tools needed in applications of mathematics in directly implementable form   *4th AIAA Theoretical Fluid Mechanics Meeting: 05-4669 - 05-4941* ,2005   Numerical Methods with Fortran IV Case Studies William S. Dorn,Daniel D. McCracken,1972   *Lectures on Clinical Medicine* Armand Trousseau,1873   Clinical Medicine Armand Trousseau,1882   *Numerical Methods in Laminar and Turbulent Flow* ,1991   HTFS Digest ,1985

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