NUMERICAL METHODS

LEAST SQUARES REGRESSION:

GOAL: MINIMIZE THE SUM OF THE SQUARE OF THE RESIDUAL ERRORS

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

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

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

$$a_0 = \bar{y} - a_1 x$$

$$y = a_0 + a_1 x$$

POLYNOMIAL (QUADRATIC) REGRESSION:

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

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

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

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

$$\sum a_i = a_i n$$

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

$$S_{y/x} = \sqrt{\frac{S_r}{n-(m+1)}}$$

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

STANDARD ERROR:

$$S_y = \sqrt{\frac{S_r}{n-2}} \qquad S_{y/x} = \sqrt{\frac{\sum (z_i - y_i^m)^2}{n-2}}$$

STAND DEVIATION:

$$S_y = \sqrt{\frac{S_t}{n-1}} \qquad S_x = \sqrt{\frac{\sum (z_i - \bar{y})^2}{n-1}}$$

INTERPOLATION

USE A POLYNOMIAL FIT:

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

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

ORDER: n=1, n=2, n=3, n=4

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:
$$\frac{dy}{dx} = f(x,y)$$
$$\frac{dy}{dx} = y_i' = f(x_i, y_i)$$
$$\frac{dy}{dx} = y_i' = f(x_i, y_i)$$
$$y^0 = \frac{y_i + y_{i+1}}{2}, \quad \frac{f(x_i,y_i) + f(x_{i+1}, y_{i+1}^0)}{2}$$
$$y_{i+1} = y_i + \frac{f(x_i, y_i) + f(x_{i+1}, y_{i+1})}{2} \Delta x$$

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:
$$y_{i+1} = y_i + \Delta x \sum a_i k_i$$
$$y_{i+1} = y_i + \Delta x \sum b_i k_i$$

EIGEN VALUES

λ = EIGEN VALUE

SIMPLE 2×2:
$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \qquad [A]^{-1} = \frac{1}{\det(A)}\begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$
$$[X] = \frac{1}{\det(A)}\begin{bmatrix} d & -b \\ -c & a \end{bmatrix}[B]$$
$$\begin{bmatrix} a-\lambda & b \\ c & d-\lambda \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$
$$\lambda = \frac{(a+d) \pm \sqrt{(a+d)^2 - 4(ad - bc)}}{2}$$

PDE'S

FINITE DIFFERENCE METHOD:

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

TEMPERATURE

DIRICHLET:

BC:
- TEMP KNOWN @ BOUNDARY

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

NEUMANN:

BC:
- TEMP DERIVATIVE KNOWN ON BOUNDARY

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

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:
$$u_{i-1,j} + 4u_{i,j} - u_{i,j-1} - u_{i,j+1} = 2\Delta x q_x$$
$$-2u_{i+1,j} + 4u_{i,j} - u_{i,j-1} - u_{i,j+1} = -2\Delta x q_x$$
RIGHT:
$$-2u_{i-1,j} + 4u_{i,j} - u_{i,j-1} - u_{i,j+1} = -2\Delta x q_x$$
BOTTOM:
$$-u_{i-1,j} - u_{i+1,j} + 4u_{i,j} - 2u_{i,j+1} = -2\Delta y q_y$$
TOP:
$$-u_{i-1,j} - u_{i+1,j} + 4u_{i,j} - 2u_{i,j-1} = -2\Delta y q_y$$

MISC EQN'S:
CENTERED FINITE-DIVIDED DIFF FORMULAS:
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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