

# 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 Error =  $y_i - \hat{y}_i$

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

$$a_0 = \frac{\sum y_i}{n} - a_1 \frac{\sum x_i}{n} \Rightarrow a_0 = 5 - 0.8$$

## 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:

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

$$a_0 = 5 - 0.8x$$

## 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.

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

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

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

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

Use Gauss-Jordan elimination to solve for  $a_0, a_1, a_2$ .

## INTERPOLATION

Use a polynomial  $P(x)$

LAGRANGE	HERMITE	LAGRANGE	LAGRANGE
2 pts 1 interval 1 degree	3 points 2 intervals 2 degree	4 pts 3 intervals 3 degree	5 pts 4 intervals 4 degree
$P(x) = a_0 + a_1 x + a_2 x^2 + \dots + a_n x^n$			
ORDER		TURNS	SPLINES:
$n=1$	—	0	$P_1 = \frac{f(x_{i+1}) - f(x_i)}{x_{i+1} - x_i}$
$n=2$	—	1	
$n=3$	—	2	
$n=4$	—	3	
$n=5$	—	4	

## ODE'S

### EULER METHOD

$$\frac{dy}{dx} = f(x,y) \quad y_{i+1} = y_i + f(x_i, y_i) \Delta x$$

### HEUN'S METHOD

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

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

$$y_{i+1} = y_i + \frac{f(x_i, y_i) + f(x_{i+1}, y_{i+1})}{2} \Delta x$$

Taylor Series:  
 $y(x+\Delta x) = y(x) + \Delta x y'(x) + \frac{\Delta x^2}{2} y''(x) + \dots$   
 $y(x+\Delta x) = y(x) + f(x,y) \Delta x$

### CLASSIC 4th ORDER RUNGE-KUTTA

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

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

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

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

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

## PDE'S

### FINITE DIFFERENCE METHOD



Problem:  $T_x = 0$  at  $x=0$ ,  $T_x = 0$  at  $x=L$

Central Difference:

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

$$u_{i,j}(t) = \frac{u_{i,j+1}(t) - u_{i,j-1}(t)}{2\Delta y}$$

## EIGEN VALUES

Example:  $A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$

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

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

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

Single 2x2:

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

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

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

Find Eigen Vectors:

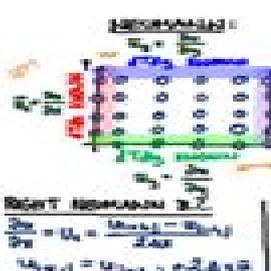
$$\begin{bmatrix} a-\lambda & b \\ c & d-\lambda \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

Example:  $\begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$

$x_1 = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$

Example:  $\begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$

$x_2 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$



Central Difference:

$$\frac{\partial^2 u}{\partial x^2} = \frac{u_{i+1,j} - 2u_{i,j} + u_{i-1,j}}{\Delta x^2}$$

5th row of A matrix:

$$\begin{bmatrix} 0 & -1 & 0 & -1 & 4 & -1 & 0 & -1 & 0 \end{bmatrix} u = 0$$

[A] MATRIX:

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

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

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

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

5th row of A matrix:

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

Finite Difference:

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

$$f(x) = \frac{f(x+\Delta x) + 3f(x) - 3f(x-\Delta x) + f(x)}{4\Delta x}$$

# Numerical Analysis Using R

**Puja Mehta**



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web c the nut may need to be slightly tightened or loosened to meet the required end play d rotated counterclockwise against the retainer nut e use a hammer and staking tool to stake the stake washer to the spindle nut in three positions conventional wheel end systems initial adjusting nut torque a final adjusting nut torque c spindle thread

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web wheel nut checking important in addition to the maintenance interval in this manual check the wheel nut torque the first 50 to 100 miles 80 to 160 km of operation after a wheel has been removed and installed when checking wheel nuts on a stud piloted dual disc assembly remove one outer nut at a time tighten the inner nut then reinstall

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web to place the nut on the spindle or tighten or loosen the nut on the spindle while the keeper is installed inside the nut doing so may deform the keeper and allow the nut to unthread during operation spindle thread damage could also occur leaving the axle unusable do not bend or manipulate keyway tang in any way

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web the spindle nut system if the locking device can not be engaged advance the spindle nut until the lock can be engaged double jam nut systems torque the inner spindle nut to 300 ft lbs while rotating the hub advance the inner nut as necessary to engage the locking ring do not back off the spindle nut install the

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web needed then tighten the yoke nut refer to group 41 of the cascadiatm workshopmanual fortorquespecifications iftheyokeis stillloose after tightening the yokenut replace the end yoke and yoke nut replace the prevailing torque locknut end yoke nut if it was removed for yoke replacement seal replacement or any other reason 4

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web the tramec sloan line now includes the industry's best spindle nuts the original axilok by metform a division of maclean fogg component solutions installation should take less than half the time required for the old style 3 piece systems still greater time savings are realized with axilok when adjustments are needed

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web inner spindle nut torque a outer nut torque out of service end play criteria trailer two piece nut system preset by meritor 300 lb ft 408 n m 200 lb ft 272 n m 0 006 0 1524 mm or more service the preset hub assembly nut torque acceptable end play criteria b trailer single nut system pro torq 200 lb ft 272 n m back off until loose

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web step 1 bearing lubrication lubricate the wheel bearing with clean lubricant of the same type used in the axle sump or hub assembly step 2 initial adjusting nut torque tighten the adjusting nut to torque of 200 ft lbs while rotating the wheel step 3 initial back off back the adjusting nut off one full turn step 4

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web install the inner spindle nut and torque to 300 ft lbs do not back off the spindle nut engage the locking device that is part of the spindle nut system if the locking system cannot be engaged when the nut is at 300 ft lbs advance the nut until the locking system can be engaged reference note above

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