



# SNS COLLEGE OF TECHNOLOGY

(An Autonomous Institution)

Approved by AICTE, New Delhi, Affiliated to Anna University, Chennai

Accredited by NAAC-UGC with 'A++' Grade (Cycle III) &

Reaccredited by NBA (B.E - CSE, EEE, ECE, Mech&B.Tech.IT)

COIMBATORE-641 035, TAMIL NADU



1. Find the eigen value and eigen vector of the matrix

$$\begin{bmatrix} 2 & 1 & -1 \\ 1 & 1 & -2 \\ -1 & -2 & 1 \end{bmatrix}$$

Symmetric matrix with non repeated eigen values.

Let  $A = \begin{bmatrix} 2 & 1 & -1 \\ 1 & 1 & -2 \\ -1 & -2 & 1 \end{bmatrix}$

Step-I :- To find the charac eqn  
The characteristic equation is given by

$$\lambda^3 - S_1\lambda^2 + S_2\lambda - S_3 = 0.$$

$S_1 =$  Sum of diagonal elements  
 $= 2 + 1 + 1 = 4$

$$S_2 = \begin{vmatrix} 1 & -2 \\ -2 & 1 \end{vmatrix} + \begin{vmatrix} 2 & -1 \\ -1 & 1 \end{vmatrix} + \begin{vmatrix} 2 & 1 \\ 1 & 1 \end{vmatrix}$$
$$= (1-4) + (2-1) + 2(-1)$$
$$= -3 + 1 + 1$$
$$S_2 = -1$$
$$S_3 = |A| = 2(-3) - 1(-1) - 1(-1)$$
$$= -6 + 1 + 1 = -4$$

$S_3 = -4$



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Step: 2. The characteristic equation is  $\lambda^3 - 4\lambda^2 - \lambda + 4 = 0$   
To solve charac eqn:-

$$\begin{array}{ccc|ccc} & & & 1 & -4 & -1 & 4 \\ & & & \downarrow & & & \\ 1 & & & 1 & -3 & -4 & \\ \hline & & & 1 & -3 & -4 & 0 \end{array}$$
$$\lambda^2 - 3\lambda - 4 = 0$$
$$(\lambda^2 - 4\lambda + \lambda - 4) = 0$$
$$(\lambda - 4)(\lambda + 1) = 0$$

$\therefore$  Eigen values are  $-1, 1, 4$

Step: 3  
To find eigen vectors:-

$X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$  satisfies the equation

$$(A - \lambda I)x = 0$$
$$\begin{bmatrix} 2-\lambda & 1 & -1 \\ 1 & 1-\lambda & -2 \\ 1 & -2 & 1-\lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = 0$$
$$(2-\lambda)x_1 + x_2 - x_3 = 0$$
$$+x_1 + (1-\lambda)x_2 - 2x_3 = 0$$
$$-x_1 - 2x_2 + (1-\lambda)x_3 = 0$$



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Case -I  $\lambda = -1$

$$3x_1 + x_2 - x_3 = 0 \rightarrow \textcircled{1}$$
$$x_1 + 2x_2 - 2x_3 = 0 \rightarrow \textcircled{2}$$
$$-x_1 - 2x_2 + 2x_3 = 0 \rightarrow \textcircled{3}$$

Consider  $\textcircled{1}$  &  $\textcircled{2}$

$x_1$	$x_2$	$x_3$	
1	-1	3	1
2	-2	1	2

$$\frac{x_1}{-2+2} = \frac{x_2}{-1+6} = \frac{x_3}{6-1}$$
$$\Rightarrow \frac{x_1}{0} = \frac{x_2}{5} = \frac{x_3}{5} \quad \left(\frac{1}{5}\right)$$
$$\Rightarrow x_1 = 0 \quad x_2 = 1 \quad x_3 = 1$$
$$x_1 = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$$

Case -II  $\lambda = 1$

$$x_1 + x_2 - x_3 = 0 \rightarrow \textcircled{1}$$
$$x_1 + 0x_2 - 2x_3 = 0 \rightarrow \textcircled{2}$$
$$-x_1 - 2x_2 + 0x_3 = 0 \rightarrow \textcircled{3}$$



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Consider ① & ②

$x_1$	$x_2$	$x_3$	
1	-1	1	-1
0	-2	1	0

$$\frac{x_1}{-2-0} = \frac{x_2}{-1+2} = \frac{x_3}{0-1}$$
$$\Rightarrow \frac{x_1}{-2} = \frac{x_2}{1} = \frac{x_3}{-1} \quad (\times \text{ by } -1)$$
$$x_2 = \begin{bmatrix} 2 \\ -1 \\ 1 \end{bmatrix}$$

Case - iii  $\lambda = 4$

$$-2x_1 + x_2 - x_3 = 0 \rightarrow \textcircled{1}$$
$$x_1 - 3x_2 - 2x_3 = 0 \rightarrow \textcircled{2}$$
$$-x_1 - 2x_2 - 3x_3 = 0 \rightarrow \textcircled{3}$$

Considering ① & ②

$x_1$	$x_2$	$x_3$	
1	-1	-2	1
-3	-2	1	-3

$$\frac{x_1}{-2+3} = \frac{x_2}{-1-4} = \frac{x_3}{+6-1} \Rightarrow \frac{x_1}{-5} = \frac{x_2}{-5} = \frac{x_3}{+5}$$



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$$\Rightarrow \frac{x_1}{1} = \frac{x_2}{1} = \frac{x_3}{-1}$$

$$x_3 = \begin{bmatrix} 1 \\ 1 \\ -1 \end{bmatrix}$$

Characteristic Equation	Eigen Value	Eigen Vector
$\lambda^2 - 4\lambda + 4 = 0$	$\lambda = -1$	$x_1 = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$
	$\lambda = 1$	$x_2 = \begin{bmatrix} 2 \\ -1 \\ 1 \end{bmatrix}$
	$\lambda = 4$	$x_3 = \begin{bmatrix} 1 \\ 1 \\ -1 \end{bmatrix}$

2. Find the eigen values and eigen vectors

i)  $\begin{bmatrix} 1 & 1 & 3 \\ 1 & 5 & 1 \\ 3 & 1 & 1 \end{bmatrix}$       ii)  $\begin{bmatrix} 2 & 0 & -1 \\ 0 & 2 & 0 \\ -1 & 0 & 2 \end{bmatrix}$

i) Solution:-

Let  $A = \begin{bmatrix} 1 & 1 & 3 \\ 1 & 5 & 1 \\ 3 & 1 & 1 \end{bmatrix}$

The characteristic equation is

$$\lambda^3 - S_1\lambda^2 + S_2\lambda - S_3 = 0.$$



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$(A - \lambda I) \underline{x} = 0$       $\lambda \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

$$\begin{bmatrix} 1-\lambda & 1 & 3 \\ 1 & 5-\lambda & 1 \\ 3 & 1 & 1-\lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = 0$$

$(1-\lambda)x_1 + x_2 + 3x_3 = 0$   
 $x_1 + (5-\lambda)x_2 + x_3 = 0$   
 $3x_1 + x_2 + (1-\lambda)x_3 = 0$

Case - I when  $\lambda = -2$

$$3x_1 + x_2 + 3x_3 = 0 \rightarrow \textcircled{1}$$
$$x_1 + 7x_2 + x_3 = 0 \rightarrow \textcircled{2}$$
$$3x_1 + x_2 + 3x_3 = 0 \rightarrow \textcircled{3}$$

Consider  $\textcircled{1}$  &  $\textcircled{2}$

$x_1$	$x_2$	$x_3$	
1	3	3	1
7	1	1	7

$$\frac{x_1}{-20} = \frac{x_2}{0} = \frac{x_3}{20}$$
$$\frac{x_1}{-1} = \frac{x_2}{0} = \frac{x_3}{1} \Rightarrow x_1 = \begin{pmatrix} 1 \\ 0 \\ -1 \end{pmatrix} \otimes \begin{pmatrix} -1 \\ 0 \\ 1 \end{pmatrix}$$



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$$S_1 = \text{Sum of the diagonal elements} \\ = 1 + 5 + 1$$

$$= 7$$

$$S_2 = \text{Sum of the minors of diagonal elements}$$

$$= \begin{vmatrix} 5 & 1 \\ 1 & 1 \end{vmatrix} + \begin{vmatrix} 1 & 3 \\ 3 & 1 \end{vmatrix} + \begin{vmatrix} 1 & 1 \\ 1 & 5 \end{vmatrix}$$

$$= (5-1) + (1-9) + (5-1)$$

$$= 8 - 8 = 0.$$

$$S_3 = |A| = 1(4) - 1(-2) + 3(-14)$$

$$= 4 + 2 - 42$$

$$= -36.$$

∴ The characteristic equation is

$$\lambda^3 - 7\lambda^2 + 36 = 0.$$

$$\begin{array}{r|rrr} 1 & -7 & 0 & 36 \\ -2 & \downarrow & -2 & 18 & -36 \\ \hline & 1 & -9 & 18 & 0 \end{array}$$

$$\lambda^2 - 9\lambda + 18 = 0 \Rightarrow \lambda^2 - 6\lambda - 3\lambda + 18 = 0.$$

$$\lambda = 6, 3, -2$$

∴ Eigen values are -2, 3, 6

$$X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \text{ satisfies the equation.}$$





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Case II  $\lambda=3$

$$-2x_1 + x_2 + 3x_3 = 0 \rightarrow \textcircled{1}$$

$$x_1 + 2x_2 + x_3 = 0 \rightarrow \textcircled{2}$$

$$3x_1 + x_2 - 2x_3 = 0 \rightarrow \textcircled{3}$$

Consider  $\textcircled{1}$  &  $\textcircled{2}$

$$\begin{array}{cccc} x_1 & x_2 & x_3 & \\ 1 & 3 & -2 & 1 \\ 2 & 1 & 1 & 2 \end{array}$$

$$\frac{x_1}{1-6} = \frac{x_2}{3+2} = \frac{x_3}{-4-1} \Rightarrow \frac{x_1}{-5} = \frac{x_2}{5} = \frac{x_3}{-5}$$

$$\frac{x_1}{1} = \frac{x_2}{-1} = \frac{x_3}{1} \therefore x_2 = \begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}$$

Case -III when  $\lambda=6$

$$-5x_1 + x_2 + 3x_3 = 0 \rightarrow \textcircled{1}$$

$$x_1 - x_2 + x_3 = 0 \rightarrow \textcircled{2}$$

$$3x_1 + x_2 - 5x_3 = 0 \rightarrow \textcircled{3}$$

Consider  $\textcircled{1}$  &  $\textcircled{2}$

$$\begin{array}{cccc} x_1 & x_2 & x_3 & \\ 1 & 3 & -5 & 1 \\ -1 & 1 & 1 & -1 \end{array}$$

$$\frac{x_1}{1+3} = \frac{x_2}{3+5} = \frac{x_3}{5-1}$$



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$$\frac{x_1}{4} = \frac{x_2}{8} = \frac{x_3}{4}$$

$$\frac{x_1}{1} = \frac{x_2}{2} = \frac{x_3}{1} \quad \therefore X_3 = \begin{pmatrix} 1 \\ 2 \\ 1 \end{pmatrix}$$

- x -

ii) Let  $A = \begin{bmatrix} 2 & 0 & -1 \\ 0 & 2 & 0 \\ -1 & 0 & 2 \end{bmatrix}$

The characteristic equation is

$$\lambda^3 - S_1\lambda^2 + S_2\lambda - S_3 = 0.$$

$S_1 =$  Sum of the diagonal elements

$$= 2 + 2 + 2 = 6.$$

$S_2 =$  Sum of the minors of the diagonal elements

$$= \begin{vmatrix} 2 & 0 \\ 0 & 2 \end{vmatrix} + \begin{vmatrix} 2 & -1 \\ -1 & 2 \end{vmatrix} + \begin{vmatrix} 2 & 0 \\ 0 & 2 \end{vmatrix}$$

$$= 4 + 3 + 4 = 11$$

$$S_3 = |A| = 2(4) - 0(6) - 1(0+2)$$

$$= 8 - 2 = 6.$$

$\therefore$  The characteristic equation is

$$\lambda^3 - 6\lambda^2 + 11\lambda - 6 = 0.$$



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$$\begin{array}{cccc|c} & 1 & -6 & 11 & -6 & \\ & \downarrow & & & & \\ 1 & & 1 & -5 & 6 & \\ \hline & 1 & -5 & 6 & & 0 \end{array}$$

$$\therefore \lambda^2 - 5\lambda + 6 = 0$$

$$\Rightarrow \lambda - 3\lambda - 2\lambda + 6 = 0$$

$$\Rightarrow (\lambda - 3)(\lambda - 2) = 0$$

$\therefore$  Eigen values are 1, 2, 3

$$X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \text{ satisfies the equation } (A - \lambda I)X = 0$$

$$\begin{bmatrix} 2-\lambda & 0 & -1 \\ 0 & 2-\lambda & 0 \\ -1 & 0 & 2-\lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = 0.$$

$$(2-\lambda)x_1 + x_3 = 0.$$

$$(2-\lambda)x_2 = 0.$$

$$-x_1 + (2-\lambda)x_3 = 0$$

Case I. When  $\lambda = 1$

$$x_1 + x_3 = 0$$

$$x_2 = 0$$

$$-x_1 + x_3 = 0$$

$$x_1 + 0x_2 + x_3 = 0 \rightarrow \textcircled{1}$$

$$0x_1 + x_2 + 0x_3 = 0 \rightarrow \textcircled{2}$$

$$-x_1 + 0x_2 + x_3 = 0 \rightarrow \textcircled{3}$$



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from ① & ②

$$\begin{array}{cccc} & x_1 & & x_2 & & x_3 & & \\ 0 & & -1 & & 1 & & 0 & \\ 1 & & 0 & & 0 & & 1 & \end{array}$$
$$\frac{x_1}{1} = \frac{x_2}{0} = \frac{x_3}{1} \Rightarrow x_1 = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}$$

Case - ii. When  $\lambda = 2$

$$0x_1 + 0x_2 - x_3 = 0 \rightarrow \textcircled{1}$$
$$0x_1 + 0x_2 + 0x_3 = 0 \rightarrow \textcircled{2}$$
$$-x_1 + 0x_2 + 0x_3 = 0 \rightarrow \textcircled{3}$$

Consider ① & ③

$$\begin{array}{cccc} & x_1 & & x_2 & & x_3 & & \\ 0 & & -1 & & 0 & & 0 & \\ 0 & & 0 & & -1 & & 0 & \\ 0 & & 0 & & 0 & & 0 & \end{array}$$
$$\frac{x_1}{0} = \frac{x_2}{1} = \frac{x_3}{0} \Rightarrow x_2 = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$

Case (ii)  $\lambda = 3$

$$-x_1 + 0x_2 - x_3 = 0 \rightarrow \textcircled{1}$$
$$0x_1 - x_2 + 0x_3 = 0 \rightarrow \textcircled{2}$$
$$-x_1 + 0x_2 - x_3 = 0 \rightarrow \textcircled{3}$$

Consider ① & ②

$$\begin{array}{cccc} & x_1 & & x_2 & & x_3 & & \\ 0 & & -1 & & -1 & & 0 & \\ -1 & & 0 & & 0 & & -1 & \end{array}$$



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$$\frac{x_1}{-1} = \frac{x_2}{0} = \frac{x_3}{1}$$
$$\frac{x_1}{1} = \frac{x_2}{0} = \frac{x_3}{-1} \quad \therefore X_3 = \begin{bmatrix} 1 \\ 0 \\ -1 \end{bmatrix}$$

Characteristic equation

$$\lambda^3 - 6\lambda^2 + 11\lambda - 6 = 0$$

Eigen values

$$\lambda = 1$$
$$\lambda = 2$$
$$\lambda = 3$$

Eigen vector

$$X_1 = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}$$
$$X_2 = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$
$$X_3 = \begin{bmatrix} 1 \\ 0 \\ -1 \end{bmatrix}$$



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Problems based on Non Symmetric Matrix with Repeated Eigen values.

$$\begin{pmatrix} -2 & 2 & -3 \\ 2 & 1 & -6 \\ -1 & -2 & 0 \end{pmatrix}$$

Step 1:-

$$S_1 = -2 + 1 + 0 = -1$$

$$S_2 = \begin{vmatrix} 1 & -6 \\ -2 & 0 \end{vmatrix} + \begin{vmatrix} -2 & -3 \\ -1 & 0 \end{vmatrix} + \begin{vmatrix} -2 & -3 \\ 2 & 1 \end{vmatrix}$$
$$= (0 - 12) + (0 - 3) + (-2 - 4)$$
$$= -21$$

$$S_3 = -2(-12) - 2(0 - 6) - 3(-4 + 1)$$
$$= 24 + 12 + 9 = 45$$

∴ The characteristic eqn is  $\lambda^3 + \lambda^2 + 21\lambda - 45 = 0$ .

Step: 2.  $\lambda = 5, -3, -3$ .

Step 3:- To find the Eigen vectors

To find Eigen vectors solve  $(A - \lambda I) \mathbf{x} = 0$

$$\begin{bmatrix} (-2-\lambda) & 2 & -3 \\ 2 & 1-\lambda & -6 \\ -1 & -2 & 0-\lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = 0$$

$$\begin{cases} (-2-\lambda)x_1 + 2x_2 - 3x_3 = 0 \\ 2x_1 + (1-\lambda)x_2 - 6x_3 = 0 \\ -x_1 - 2x_2 - \lambda x_3 = 0 \end{cases} \rightarrow \text{⊕}$$

Case 1) when  $\lambda = 5$

$$-7x_1 + 2x_2 - 3x_3 = 0 \rightarrow \text{①}$$

$$2x_1 - 4x_2 - 6x_3 = 0 \rightarrow \text{②}$$

$$-x_1 - 2x_2 - 5x_3 = 0 \rightarrow \text{③}$$

Consider ① & ②

$$\begin{array}{ccc} x_1 & x_2 & x_3 \\ 2 & -3 & -3 \\ -4 & -6 & -6 \end{array}$$



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$$\frac{x_1}{-12-12} = \frac{x_2}{-6-42} = \frac{x_3}{+28+4}$$

(b) 
$$\frac{x_1}{-24} = \frac{x_2}{-48} = \frac{x_3}{+24} \Rightarrow \frac{x_1}{1} = \frac{x_2}{2} = \frac{x_3}{-1}$$

$$\Rightarrow x_1 = \begin{bmatrix} 1 \\ 2 \\ -1 \end{bmatrix} \text{ or } \begin{bmatrix} -1 \\ -2 \\ 1 \end{bmatrix}$$

Case (ii)

When  $\lambda = -3$ .

$$x_1 + 2x_2 - 3x_3 = 0 \rightarrow \textcircled{1}$$

$$2x_1 + 4x_2 - 6x_3 = 0 \rightarrow \textcircled{2}$$

$$-x_1 - 2x_2 + 3x_3 = 0 \rightarrow \textcircled{3}$$

All three eqns are same eqns.

$\therefore x_1 + 2x_2 - 3x_3 = 0$ .

Put  $x_1 = 0$ .  $2x_2 - 3x_3 = 0$

$$\Rightarrow 2x_2 = 3x_3$$

$$\frac{x_2}{3} = \frac{x_3}{2}$$

$\therefore x_2 = \begin{bmatrix} 0 \\ 3 \\ 2 \end{bmatrix}$

Put  $x_2 = 0$ .

$$x_1 + 0 - 3x_3 = 0$$

$$x_1 = 3x_3$$

$$\frac{x_1}{3} = \frac{x_3}{1} \Rightarrow x_3 = \begin{bmatrix} 3 \\ 0 \\ 1 \end{bmatrix}$$

Result

Char eqn

$$\lambda^3 + \lambda^2 - 21\lambda - 45 = 0$$

Eigen value

$$\lambda = -3$$

$$\lambda = -3$$

$$\lambda = 5$$

Eigen vec

$$x_1 = \begin{bmatrix} 1 \\ 2 \\ -1 \end{bmatrix}$$

$$x_2 = \begin{bmatrix} 3 \\ 0 \\ 1 \end{bmatrix}$$

$$x_3 = \begin{bmatrix} 3 \\ 0 \\ 1 \end{bmatrix} \alpha \begin{bmatrix} 1 \\ 2 \\ -1 \end{bmatrix}$$



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