

EE5609: Matrix Theory

Assignment-4

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Abstract—This document contains solution to determine the conic representing the given equation.

Download the latex-tikz codes from latex-tikz codes from

<https://github.com/>

1 PROBLEM

What conic does the following equation represent.

$$y^2 - 2\sqrt{3}xy + 3x^2 + 6x - 4y + 5 = 0$$

Find the center and equation referred to centre.

2 SOLUTION

The general second degree equation can be expressed as follows,

$$\mathbf{x}^T \mathbf{V} \mathbf{x} + 2\mathbf{u}^T \mathbf{x} + f = 0 \quad (2.0.1)$$

From the given second degree equation we get,

$$\mathbf{V} = \begin{pmatrix} 3 & -\sqrt{3} \\ -\sqrt{3} & 1 \end{pmatrix} \quad (2.0.2)$$

$$\mathbf{u} = \begin{pmatrix} 3 \\ -2 \end{pmatrix} \quad (2.0.3)$$

$$f = 4 \quad (2.0.4)$$

Expanding the determinant of \mathbf{V} we observe,

$$\begin{vmatrix} 3 & -\sqrt{3} \\ -\sqrt{3} & 1 \end{vmatrix} = 0 \quad (2.0.5)$$

Also

$$\begin{vmatrix} \mathbf{V} & \mathbf{u} \\ \mathbf{u}^T & f \end{vmatrix} = \begin{vmatrix} 3 & -\sqrt{3} & 3 \\ -\sqrt{3} & 1 & -2 \\ 3 & -2 & 5 \end{vmatrix} \neq 0 \quad (2.0.6)$$

Hence from (2.0.5) and (2.0.6) we conclude that given equation is a parabola. The characteristic equation of \mathbf{V} is given as follows,

$$|\mathbf{V} - \lambda \mathbf{I}| = \begin{vmatrix} 3 - \lambda & -\sqrt{3} \\ -\sqrt{3} & 1 - \lambda \end{vmatrix} = 0 \quad (2.0.7)$$

$$\implies \lambda^2 - 4\lambda = 0 \quad (2.0.8)$$

Hence the characteristic equation of \mathbf{V} is given by (2.0.8). The roots of (2.0.8) i.e the eigenvalues are given by

$$\lambda_1 = 0, \lambda_2 = 4 \quad (2.0.9)$$

The eigen vector \mathbf{p} is defined as,

$$\mathbf{V} \mathbf{p} = \lambda \mathbf{p} \quad (2.0.10)$$

$$\implies (\mathbf{V} - \lambda \mathbf{I}) \mathbf{p} = 0 \quad (2.0.11)$$

for $\lambda_1 = 0$,

$$(\mathbf{V} - \lambda_1 \mathbf{I}) = \begin{pmatrix} 3 & -\sqrt{3} \\ -\sqrt{3} & 1 \end{pmatrix} \xrightarrow[R_1 = \frac{1}{\sqrt{3}} R_1]{R_2 = R_1 + R_2} \begin{pmatrix} \sqrt{3} & -1 \\ 0 & 0 \end{pmatrix} \quad (2.0.12)$$

Substituting equation 2.0.12 in equation 2.0.11 we get

$$\implies \mathbf{p}_1 = \begin{pmatrix} 1 \\ \sqrt{3} \end{pmatrix} \quad (2.0.13)$$

Again, for $\lambda_2 = 4$,

$$(\mathbf{V} - \lambda_2 \mathbf{I}) = \begin{pmatrix} -1 & -\sqrt{3} \\ -\sqrt{3} & -3 \end{pmatrix} \xrightarrow[R_1 = -\sqrt{3} R_1]{R_2 = -\sqrt{3} R_1 + R_2} \begin{pmatrix} 1 & \sqrt{3} \\ 0 & 0 \end{pmatrix} \quad (2.0.14)$$

Substituting equation 2.0.14 in equation 2.0.11 we get

$$\mathbf{p}_2 = \begin{pmatrix} -\sqrt{3} \\ 1 \end{pmatrix} \quad (2.0.15)$$

The matrix \mathbf{P} ,

$$\mathbf{P} = (\mathbf{p}_1 \quad \mathbf{p}_2) = \begin{pmatrix} 1 & -\sqrt{3} \\ \sqrt{3} & 1 \end{pmatrix} \quad (2.0.16)$$

$$\mathbf{D} = \begin{pmatrix} 0 & 0 \\ 0 & 4 \end{pmatrix} \quad (2.0.17)$$

$$\eta = 2\mathbf{p}_1^T \mathbf{u} = 6 - 4\sqrt{3} \approx 1 \quad (2.0.18)$$

The focal length of the parabola is given by:

$$\left| \frac{\eta}{\lambda_2} \right| = \frac{1}{4} \quad (2.0.19)$$

When $|\mathbf{V}| = 0$, (2.0.1) can be written as

$$\mathbf{y}^T \mathbf{D} \mathbf{y} = -\eta \begin{pmatrix} 1 & 0 \end{pmatrix} \mathbf{y} \quad (2.0.20)$$

And the vertex \mathbf{c} is given by

$$\begin{pmatrix} \mathbf{u}^T + \eta \mathbf{p}_1^T \\ \mathbf{V} \end{pmatrix} \mathbf{c} = \begin{pmatrix} -f \\ \eta \mathbf{p}_1 - \mathbf{u} \end{pmatrix} \quad (2.0.21)$$

using equations (2.0.3),(2.0.4) and (2.0.13)

$$\begin{pmatrix} 4 & -2 + \sqrt{3} \\ 3 & -\sqrt{3} \\ -\sqrt{3} & 1 \end{pmatrix} \mathbf{c} = \begin{pmatrix} -5 \\ -2 \\ 2 + \sqrt{3} \end{pmatrix} \quad (2.0.22)$$