Matrix theory Assignment 15

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***Abstract*—This document contains the concept of linear functionals.**

Download all python codes from

https://github.com/shivangi−975/EE5609−Matrix_Theory/tree/master/Assignment15/Codes

Download latex-tikz codes from

https://github.com/shivangi−975/EE5609−Matrix_Theory/blob/master/Assignment15/Assignment_15.tex

1 Problem

In R^3, let $\alpha_1 = \begin{pmatrix}1\\0\\1\end{pmatrix}$, $\alpha_2 = \begin{pmatrix}0\\1\\-2\end{pmatrix}$ and $\alpha_3 = \begin{pmatrix}-1\\-1\\0\end{pmatrix}$. Describe a linear functional f on R^3 such that $f(\alpha_1) = f(\alpha_2) = 0$ but $f(\alpha_3) \neq 0$.If α=$\begin{pmatrix}2\\3\\-1\end{pmatrix}$ such that $f(\alpha) \neq 0$

2 Solution

Let us consider $\alpha = \begin{pmatrix}a\\b\\c\end{pmatrix}$ such that

$$\alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 = \alpha \tag{2.0.1}$$

$$\alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 = \begin{pmatrix}a\\b\\c\end{pmatrix} \tag{2.0.2}$$

Hence:

$$A = \begin{pmatrix}1 & 0 & -1\\0 & 1 & -1\\1 & -2 & 0\end{pmatrix} \tag{2.0.3}$$

$$\begin{pmatrix}1 & 0 & -1\\0 & 1 & -1\\1 & -2 & 0\end{pmatrix}\begin{pmatrix}x_1\\x_2\\x_3\end{pmatrix} = \begin{pmatrix}a\\b\\c\end{pmatrix} \tag{2.0.4}$$

$x = A^{-1}\alpha$ will give solution of equation.

$$\begin{pmatrix}1 & 0 & -1 & 1 & 0 & 0\\0 & 1 & -1 & 0 & 1 & 0\\1 & -2 & 0 & 0 & 0 & 1\end{pmatrix} \xleftrightarrow{R_3 \leftarrow R_3 - R_1} \tag{2.0.5}$$

$$\begin{pmatrix}1 & 0 & -1 & 1 & 0 & 0\\0 & 1 & -1 & 0 & 1 & 0\\0 & -2 & 1 & -1 & 0 & 1\end{pmatrix} \xleftrightarrow{R_3 \leftarrow R_3 + 2R_2} \tag{2.0.6}$$

$$\begin{pmatrix}1 & 0 & -1 & 1 & 0 & 0\\0 & 1 & -1 & 0 & 1 & 0\\0 & 0 & -1 & -1 & 2 & 1\end{pmatrix} \xleftrightarrow{R_3 \leftarrow R_3/(-1)} \tag{2.0.7}$$

$$\begin{pmatrix}1 & 0 & -1 & 1 & 0 & 0\\0 & 1 & -1 & 0 & 1 & 0\\0 & 0 & 1 & 1 & -2 & -1\end{pmatrix} \xleftrightarrow{R_1 \leftarrow R_1 + R_3} \tag{2.0.8}$$

$$\begin{pmatrix}1 & 0 & 0 & 2 & -2 & -1\\0 & 1 & -1 & 0 & 1 & 0\\0 & 0 & 1 & 1 & -2 & -1\end{pmatrix} \xleftrightarrow{R_2 \leftarrow R_2 + R_3} \tag{2.0.9}$$

$$\begin{pmatrix}1 & 0 & 0 & 2 & -2 & -1\\0 & 1 & 0 & 1 & -1 & -1\\0 & 0 & 1 & 1 & -2 & -1\end{pmatrix} \tag{2.0.10}$$

Hence,

$$A^{-1} = \begin{pmatrix}2 & -2 & -1\\1 & -1 & -1\\1 & -2 & -1\end{pmatrix} \tag{2.0.11}$$

Simplifying,

$$x_1 = 2a - 2b - c \tag{2.0.12}$$

$$x_2 = a - b - c \tag{2.0.13}$$

$$x_3 = a - 2b - c \tag{2.0.14}$$

Given, f is a linear functional on R^3,

$$\alpha = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 \tag{2.0.15}$$

$$\implies f(\alpha) = x_1 f(\alpha_1) + x_2 f(\alpha_2) + x_3 f(\alpha_3) \tag{2.0.16}$$

$$\implies f(\alpha) = \mathbf{x}^T \begin{pmatrix}f(\alpha_1)\\f(\alpha_2)\\f(\alpha_3)\end{pmatrix} \tag{2.0.17}$$

Given, $f(\alpha_1) = f(\alpha_2) = 0$ and $f(\alpha_3) \neq 0$, consider $f(\alpha_3) = k$ where $k \neq 0$.

$$f(\alpha) = \begin{pmatrix} x_1 & x_2 & x_3 \end{pmatrix} \begin{pmatrix} 0 \\ 0 \\ k \end{pmatrix} \tag{2.0.18}$$

$$\implies f(\alpha) = x_3 k \tag{2.0.19}$$

$$\implies f(\alpha) = k(a - 2b - c) \tag{2.0.20}$$

$$\implies f(a, b, c) = k(a - 2b - c) \tag{2.0.21}$$

Hence function is:

$$f(x, y, z) = k(x - 2y - z) \tag{2.0.22}$$

Now to prove $f(\alpha) \neq 0$,

$$f(\alpha) = k(x - 2y - z) \tag{2.0.23}$$

$$\implies f(2, 3, -1) = k(2 - 6 + 1) \tag{2.0.24}$$

$$\implies -3k \neq 0 \tag{2.0.25}$$

Hence, proved $f(\alpha) \neq 0$