Solution of Assignment 9

Professor: Aljohh

1. (a) $Ax^1 = 9x^1$. Thus x^1 is an eigenvector of A with eigenvalue $\lambda_1 = 9$.

   (b) A is singular since row 3 is the sum of row 1 and row 2. Also one can calculate $\det A = 0$.

   (c) The characteristic polynomial of A is $\chi_A(\lambda) = \lambda(\lambda - 9)(2 + \lambda)$. Thus the other remaining eigenvalues are $\lambda_2 = 0$ and $\lambda_3 = -2$.

   (d) the trace of $A = 1 + 2 + 4 = 7 = 9 + 0 - 2$.

2.
$$S = \begin{bmatrix} 2 & 1 \\ -1 & 1 \end{bmatrix}, S^{-1} = \frac{1}{3}\begin{bmatrix} 1 & -1 \\ 1 & 2 \end{bmatrix}, \Lambda = \begin{bmatrix} 1 & 0 \\ 0 & -2 \end{bmatrix}. \text{ Thus } A = S\Lambda S^{-1} = \begin{bmatrix} 0 & -2 \\ -1 & -1 \end{bmatrix}.$$

3. (a) The characteristic polynomial of A is $\chi_A(\lambda) = (\lambda - 3)(\lambda - 5)$. Thus the eigenvalues are $\lambda_1 = 3$ and $\lambda_2 = 5$.

   (b) The orthonormal eigenvectors of A are $x^1 = \frac{1}{\sqrt{2}}\begin{bmatrix} -1 \\ 1 \end{bmatrix}$ and $x^2 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ 1 \end{bmatrix}$.

   (c)
$$A = Q\Lambda Q^T = \frac{1}{\sqrt{2}}\begin{bmatrix} -1 & 1 \\ 1 & 1 \end{bmatrix}\begin{bmatrix} 3 & 0 \\ 0 & 5 \end{bmatrix}\frac{1}{\sqrt{2}}\begin{bmatrix} -1 & 1 \\ 1 & 1 \end{bmatrix}$$

   (d)
$$A^k = Q\Lambda^k Q^T = \frac{1}{\sqrt{2}}\begin{bmatrix} -1 & 1 \\ 1 & 1 \end{bmatrix}\begin{bmatrix} 3^k & 0 \\ 0 & 5^k \end{bmatrix}\frac{1}{\sqrt{2}}\begin{bmatrix} -1 & 1 \\ 1 & 1 \end{bmatrix} = \frac{1}{2}\begin{bmatrix} 5^k + 3^k & 5^k - 3^k \\ 5^k - 3^k & 5^k + 3^k \end{bmatrix}.$$

4. (a) Since A is diagonalizable, then $A = SAS^{-1}$, where Λ is the diagonal matrix consisting of the eigenvalues of A and the columns of S are the corresponding eigenvectors. Thus, $A^2 = S\Lambda^2 S^{-1}$. Hence, A^2 is diagonalizable.

   (b) The eigenvalues of A^2 are $\lambda_1^2, \ldots, \lambda_n^2$.

   (c) $\det(A^2) = \det \Lambda^2 = \lambda_1^2 \ldots \lambda_n^2$.

   (d) the eigenvalues of A^2 are the same those of A.

5. (a) The eigenvalues of A are 2, 2 since A is upper triangular. To find the eigenvectors we need a basis of the null space of $A - 2I = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix}$. Thus there is only one eigenvector namely $x^1 = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$.

   (b) A is not diagonalizable since it has only one independent eigenvector.

6. (a) One can prove that T is a linear transformation by using the definition namely $T(\alpha x + \beta y) = \alpha T(x) + \beta T(y)$ for all $x, y \in \mathbb{R}^2$ and all scalars α and β. Also, one can use part (b), i.e., since $T(x) = Ax$, it follows that T is linear.

   (b) $A = \begin{bmatrix} 1 & -2 \\ 3 & 0 \\ 1 & 1 \end{bmatrix}$.

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