

VECTORS & MATRICES



1. DIMENSIONAL VECTORS

DEFINITIONS

General

$\vec{a} = PQ$ (where PQ = vector)
 $\vec{a} = a_1\hat{i} + a_2\hat{j} + a_3\hat{k} = |\vec{a}|(\hat{a}_1\hat{i} + \hat{a}_2\hat{j} + \hat{a}_3\hat{k})$
 $\vec{a} = |\vec{a}|(\cos\alpha\hat{i} + \cos\beta\hat{j} + \cos\gamma\hat{k})$
 $[a_1, a_2, a_3] = \text{Vector components}$

Magnitude or Length, $|\vec{a}|$ $|\vec{a}| = \sqrt{a_1^2 + a_2^2 + a_3^2}$

Unit Vector, $\hat{a}$

$\hat{a} = \cos\alpha\hat{i} + \cos\beta\hat{j} + \cos\gamma\hat{k} = \frac{\vec{a}}{|\vec{a}|}$ $|\hat{a}| = 1$
 $\hat{i}, \hat{j}, \hat{k} = \text{unit vectors along } x, y, z \text{ axes}$

Directional Cosines

$[\cos\alpha, \cos\beta, \cos\gamma]$
 $-\cos\alpha\hat{i} + \cos\beta\hat{j} + \cos\gamma\hat{k} = \hat{a}$
 $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$

Position Vector, $\vec{r}$

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$ $|\vec{r}| = \sqrt{x^2 + y^2 + z^2}$

FOUR GEOMETRIC RELATIONS

Parallel Vectors

Two non-zero vectors are parallel
 $\vec{a} \parallel \vec{b} \iff \vec{a} = k\vec{b}$ or $\sin(\angle \vec{a}, \vec{b}) = 0$

Coplanar Vectors

If $\vec{a}, \vec{b}, \vec{c}$ represent $\vec{AB}, \vec{AC}, \vec{AD}$ then A, B, C, D
 lie in plane provided: $\vec{a} \cdot (\vec{b} \times \vec{c}) = 0$

Distance d_1 Between Two Lines $\vec{AB}$ and $\vec{PQ}$

$$d_1 = \frac{|\vec{AP} \cdot \vec{AB} \times \vec{PQ}|}{|\vec{AB} \times \vec{PQ}|}$$

Distance d_2 of a Point, P , From a Plane (A, B, C)

$$d_2 = \frac{|\vec{AP} \cdot \vec{AB} \times \vec{AC}|}{|\vec{AB} \times \vec{AC}|}$$



VECTOR OPERATIONS

Vector Addition

- $\vec{a} + \vec{b} = \vec{c}$ (triangle rule)
- $\vec{a}_1 + \vec{b}_1 = \vec{c}_1$
 $\vec{a}_2 + \vec{b}_2 = \vec{c}_2$
 $\vec{a}_3 + \vec{b}_3 = \vec{c}_3$
- Addition is commutative and associative
 $\vec{a} + \vec{b} = \vec{b} + \vec{a}$
 $(\vec{a} + \vec{b}) + \vec{c} = \vec{a} + (\vec{b} + \vec{c})$
- Subtraction = addition of negative vector



Vector (Outer or Cross) Product

- $\vec{a} \times \vec{b} = \vec{c}$
 $\vec{c}$ is normal to $\vec{a}$ & $\vec{b}$
- $|\vec{a} \times \vec{b}| = |\vec{a}||\vec{b}|\sin\theta$
 $= |\vec{a}||\vec{b}|\sin\theta = |\vec{a}||\vec{b}|\sin\theta$
 $= \text{area of parallelogram}$
 $= 2 \times \text{area of triangle}$

$$\vec{a} \times \vec{b} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \end{vmatrix} = (a_2b_3 - a_3b_2)\hat{i} + (a_3b_1 - a_1b_3)\hat{j} + (a_1b_2 - a_2b_1)\hat{k}$$

- Cross product is distributive but not associative or commutative
 $\vec{a} \times (\vec{b} + \vec{c}) = \vec{a} \times \vec{b} + \vec{a} \times \vec{c}$
 $\vec{a} \times (\vec{b} \times \vec{c}) \neq (\vec{a} \times \vec{b}) \times \vec{c}$
 $\vec{a} \times \vec{b} = -\vec{b} \times \vec{a}$

Multiplication by Scalar, $\vec{a}$

- Length: $|\lambda\vec{a}| = |\lambda||\vec{a}|$
- Direction: same as $\vec{a}$ if $\lambda > 0$; opposite if $\lambda < 0$
- Multiplication by a scalar is commutative, associative and distributive
 $(\lambda\vec{a})\mu = \lambda(\mu\vec{a}) = (\lambda\mu)\vec{a}$
 $\lambda(\vec{a} + \vec{b}) = \lambda\vec{a} + \lambda\vec{b}$

Scalar (Inner or Dot) Product

- $\vec{a} \cdot \vec{b} = |\vec{a}||\vec{b}|\cos\theta$ where θ is angle between $\vec{a}$ & $\vec{b}$
 $= a_1b_1 + a_2b_2 + a_3b_3$
 $= |\vec{a}||\vec{b}|\cos\theta$
- $\vec{a} \cdot \vec{b} = 0$ if $\vec{a}$ & $\vec{b}$ are orthogonal
 $(\vec{a} \cdot \vec{b})^2 = (\vec{a} \cdot \vec{a})(\vec{b} \cdot \vec{b}) = |\vec{a}|^2|\vec{b}|^2$
 $\vec{a} \cdot \vec{a} = |\vec{a}|^2 = a_1^2 + a_2^2 + a_3^2$
 $\vec{a} \cdot \vec{a} = |\vec{a}|^2 = a_1^2 + a_2^2 + a_3^2$
 $\vec{a} \cdot \vec{a} = |\vec{a}|^2 = a_1^2 + a_2^2 + a_3^2$
- Dot product is commutative and distributive
 $\vec{a} \cdot \vec{b} = \vec{b} \cdot \vec{a}$
 $\vec{a} \cdot (\vec{b} + \vec{c}) = \vec{a} \cdot \vec{b} + \vec{a} \cdot \vec{c}$
- Repeated Product, Scalar Triple Product ($\vec{a} \cdot (\vec{b} \times \vec{c})$)

$$\vec{a} \cdot (\vec{b} \times \vec{c}) = \begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix} = |\vec{a}||\vec{b}||\vec{c}|\cos\theta$$

- Equivalent scalar triple products
 $\vec{a} \cdot (\vec{b} \times \vec{c}) = \vec{b} \cdot (\vec{c} \times \vec{a}) = \vec{c} \cdot (\vec{a} \times \vec{b})$
 $\vec{a} \cdot (\vec{b} \times \vec{c}) = \vec{b} \cdot (\vec{c} \times \vec{a}) = \vec{c} \cdot (\vec{a} \times \vec{b})$

Repeated Product, Vector Triple Product, $\vec{a} \times (\vec{b} \times \vec{c})$

$$\vec{a} \times (\vec{b} \times \vec{c}) = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix} = (\vec{a} \cdot \vec{c})\vec{b} - (\vec{a} \cdot \vec{b})\vec{c}$$



EIGENVALUES & EIGENVECTORS

DEFINITIONS

- The set of values λ , which satisfy the vector equation $A\vec{x} = \lambda\vec{x}$ are termed eigenvalues of the (square) matrix A .
- The corresponding column vectors $\vec{x}$ are known as the eigenvectors of the (square) matrix A .

PROPERTIES

- Every $n \times n$ matrix has n (real or complex) eigenvalues.
- If A is a triangular or diagonal matrix, the eigenvalues, $\lambda_1, \dots, \lambda_n$ are identical to the diagonal entries $a_{11}, \dots, a_{nn}$.
- The sum of the diagonal entries of any square matrix A equals the sum of the eigenvalues of the matrix. This sum is known as the trace of A . $\text{Tr}(A) = \sum \lambda_i$.
- The product of the eigenvalues of a matrix equals the determinant of the matrix. $|\vec{\lambda}| = \det A$.

EVALUATION

- The eigenvalues of A are the roots of the characteristic equation $\det[A - \lambda I] = 0$.
- The eigenvectors $\vec{x}_i$ of A are obtained by substitution of the eigenvalues into the vector equation: $(A - \lambda I)\vec{x} = 0$.

DETERMINANTS DEFINITIONS

Determinant

$\det A = |A| = D =$ a numerical (or functional) measure of the square matrix A .

Order of a Determinant

Number of rows or columns in D .
 $\rightarrow D = \begin{vmatrix} 2 & 1 & 3 \\ 4 & 8 & 6 \\ 0 & 7 & 5 \end{vmatrix}$ has $n=3$

Minor M_{ij} of Entry a_{ij} in Matrix A

Determinant of submatrix

$\rightarrow D = \begin{vmatrix} 2 & 1 & 3 \\ 4 & 8 & 6 \\ 0 & 7 & 5 \end{vmatrix}$ has $M_{11} = \begin{vmatrix} 8 & 6 \\ 7 & 5 \end{vmatrix}$

Cofactor A_{ij} of Entry a_{ij} in Matrix A

$$A_{ij} = (-1)^{i+j} M_{ij} \rightarrow D = \begin{vmatrix} 2 & 1 & 3 \\ 4 & 8 & 6 \\ 0 & 7 & 5 \end{vmatrix} \text{ has } A_{11} = + \begin{vmatrix} 8 & 6 \\ 7 & 5 \end{vmatrix}$$

Linear

$\vec{a} \cdot \vec{b}$
 $\vec{a} \cdot \vec{b} = |\vec{a}||\vec{b}|\cos\theta$

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**Peretz P. Friedmann, George A.
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Applied Programming for Management Narendra Paul Loomba, Efraim Turban, 1974

Fortran Library Manual, 1988 *Experiments in Computational Matrix Algebra* David Ross Hill, 1988 **Science Software**, 1988 **MATLAB for Engineers** Adrian Biran, Moshe Breiner, 1995 Divided into two parts this book provides an introduction to MATLAB with the idea that the reader will learn the program by trying the commands described in the text and by further experimenting with them The second part of the book covers applications to specific engineering fields strength analysis machine design vibrations signal processing and control engineering and demonstrates how MATLAB can solve engineering problems in these areas

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