

# MEGHNAD SAHA INSTITUTE OF TECHNOLOGY

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Stream : AI & DS  
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**Application of  
Matrix Algebra in  
Computer Science**

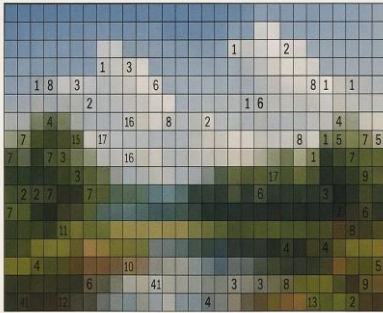
$6 \times 3$



# Introduction

Matrix algebra is a key part of computer science. It helps us manage and work with data efficiently, which is useful in everything from editing images to training AI models.

## DIGITAL IMAGE



76	126	123	121	41	63
84	116	146	165	60	62
59	117	133	146	36	32
34	90	123	152	26	37
22	89	99	99	61	35
26	69	69	58	56	28
41	120	91	120	41	20

## MATRIX OPERATIONS

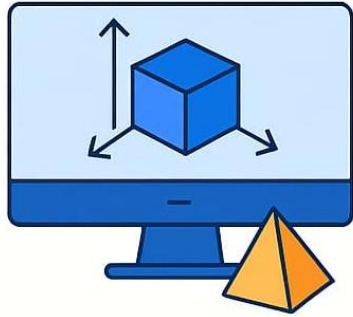
At its core, it deals with matrices—grids of numbers that let us perform operations like adding, multiplying, or changing data. For example, a digital image is just a matrix of pixel values. We can change the image's brightness, apply filters, or even reshape it using matrix operations.

In computer graphics, matrices are used to move, rotate, or resize objects in games or simulations. They make 2D and 3D animations look smooth and realistic.

In AI and machine learning, data like customer info or features are also stored as matrices. Algorithms then analyze these matrices to find patterns, train models, and make predictions. Techniques like PCA (Principal Component Analysis) help simplify big data while keeping its core meaning, and deep learning uses matrices to understand and learn from the data.

# Graphics and Image Processing

Matrices are the fundamental mathematical tools that power visual computing. They enable efficient and powerful manipulation of visual data.



## -> In Computer Graphics (2D & 3D) :

Matrices handle all kinds of transformations – moving, rotating, scaling, skewing, and flipping objects – all with compact and efficient math. They also manage complex scenes, keep track of object positions, and control how the camera sees everything. Even lighting and shading effects, like how a surface reflects light, are driven by matrix calculations.

## -> In Image Processing :





Images are just grids of pixel values (like numbers in a table). Matrix algebra helps us rotate, resize, and shift image easily. It also powers filters – like blur, sharpen, and edge detection – by applying special matrix operations. Plus, it plays a key role in advanced areas like image compression, object detection, and facial recognition.

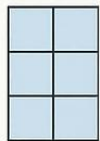


# Machine Learning & AI

## ■ Organizing the Data

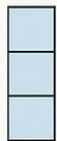
Think of a matrix as a giant table. Each row is a data point (like a photo or a sentence), and each column is a feature (like pixel values or word counts). This structure helps computers understand and work with large datasets.

-	-	-	1		
	2	4	1		
	4	8	4		
	4	2	3		
	5	5	4		

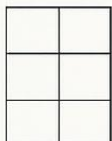


nmtrout

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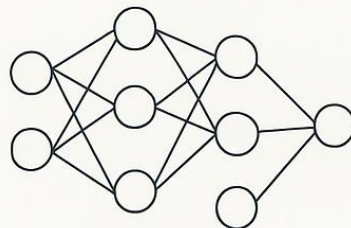
prediction

## ■ Learning Through Math

When a model learns, it's doing a lot of math behind the scenes — mainly multiplying matrices. It uses operations like the dot product to match inputs with learned patterns (called weights) and improve predictions over time.

## ■ Fueling Neural Networks

Neural networks are built almost entirely on matrix operations. Each layer of the network transforms data using matrix math, helping the model detect patterns — whether it's recognizing faces or translating languages.

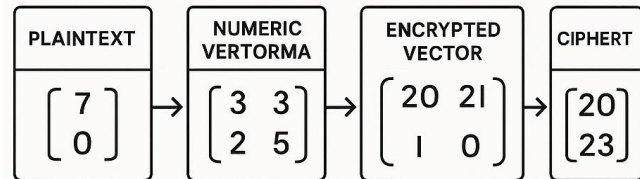


$$A = o(WX + b)$$

# Cryptography and Security

## ▪ Organizing the DaWhy Matrices Matter in Encryptionta ?

In the world of secure communication, matrix algebra plays a hidden yet powerful role. Encryption algorithms often rely on matrix transformations to scramble data into unreadable forms — only to be unscrambled by those who hold the correct key.



## ▪ The Hill Cipher – A Matrix-Based Example

The Hill cipher is a classic example where plain text is converted into numbers, grouped into vectors, and then multiplied by a secret key matrix. The encrypted message can only be decoded using the inverse of that matrix — emphasizing the importance of invertible matrices in cryptography.



## ▪ Invertibility = Security

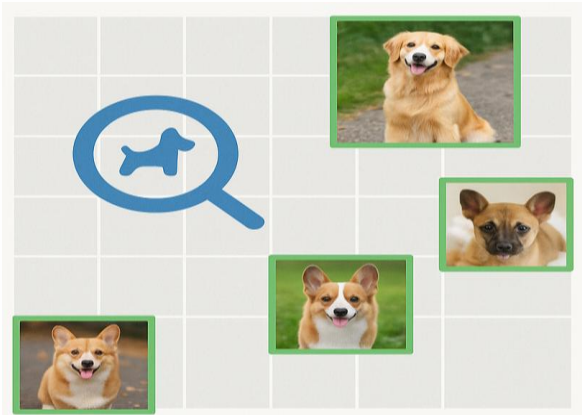
If a matrix used for encryption isn't invertible, the original message can't be recovered — making the cipher useless. Ensuring invertibility guarantees that communication is both secure and reversible.

$$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} \rightarrow \begin{bmatrix} 2 & 1 \\ \frac{1}{2} & \frac{1}{2} \end{bmatrix}$$

unlocking

# Real-World Applications and Conclusion

- Facial Recognition (e.g., Apple Face ID, Facebook Tag Suggestions) :
  - Images are stored as matrices of pixel values.
  - Algorithms perform eigenface decomposition (using eigenvectors & eigenvalues).
  - Matching is done by comparing matrix-transformed features.



Matrix overlay with icons or

- Recommendation Systems (Netflix, Amazon, Spotify) :
  - User-item interaction stored as a large sparse matrix.
  - Matrix factorization helps find hidden user preferences.
  - Predictions are made using matrix multiplication & dot products.
- Conclusion :

Matrices are everywhere in computer science — often working behind the scenes. They help us edit images, train AI, power recommendation systems, and even keep our data secure. Matrix Algebra is an essential component of computer science and its application to continue to grow and expand in various technological fields.

A =

**THANK YOU!**

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