TENSORS

? What is a tensor :

- Tensor is a **mathematical data structure** that generalizes scalars, vectors, and matrices to higher dimensions.
- It is essentially **a multi-dimensional array of numbers**.
    - So:
        - A **scalar = 0-dimensional tensor**
        - A **vector = 1-dimensional tensor**
        - A **matrix = 2-dimensional tensor**
        - A higher-order tensor = 3D or more dimensions

? Why Tensors Matter :

- Tensors are **critical in computing** because:
- **They represent data** of many shapes and sizes (images, text, videos, etc.)
- Frameworks like **TensorFlow and PyTorch depend on tensors** for **all computation**.

? What Each Tensor "Rank" Means :

- **Rank is also called Number of dimensions (ndim) and Order and number of axis**
- **Shape** tells you **the structure of a tensor** — how many elements it has per dimension.
- Each axis (or dimension) is a direction the data extends.

Example:

1. (3, 3, 3) is a 3D tensor shape — height, width, and channel.
2. Shape = (Row, Column) for 2D

Tensor Type	Rank/ Order	Dimensions Example	Use Case
Scalar	0	( )	Single loss or learning rate
Vector	1	(5)	Feature vector
Matrix	2	(Rows, Columns)	Tabular data or weight matrices
3D Tensor	3	(Height, Width, Channels)	In NLP
4D Tensor	4	(Batch, Height, Width, Channels)	RGB Images
5D Tensor	5	(Frames,Batch, Height, Width, Channels)	

A higher-order tensor continues this pattern.*

? Real World Tensor example :

Example	Type / Shape
RGB Image	3D tensor `(Height, Width, Channels)`
Grayscale image	2D tensor `(Height, Width)`
Batch of images	4D tensor `(Batch, Height, Width, Channels)`
Text sequence	2D tensor `(Batch, Sequence_length)`

? How tensors are used in Machine learning :

- Machine learning models — especially deep learning — use tensors to represent:
  - **Input Data**
    Images, text, numerical features, time sequences
  - **Weights & Parameters**
    Each layer's parameters in a neural network are stored as tensors.
  - **Intermediate Results**
    Outputs from layers are tensors too.
- This allows the network to **transform data step-by-step** by tensor operations

? Interactive Understanding (Examples) :

Think Visually

➢ Scalar: Think of a single value — like 5.
➢ Vector: Think of a row of values — like a list.
➢ Matrix: Think of a grid of numbers.
➢ Tensor: Think of stacked grids, or grids within grids.

Analogy

➢ Scalar: one point
➢ Vector: line (1D)
➢ Matrix: sheet (2D)
➢ Tensor: block of sheets (3D+)

Example:

- arr = [1,2,3,4] => Tensor
- Dimension/Rank/Order = 1D
- Shape = (4)
- Size = 4*1 (1 row 4 cols)
- Vector elements = 4 because 1D tensor contains 4 elements

- arr2 = [[1,2,3,4],[5,6,7,8]] => Tensor
- Dimension/Rank/Order = 2D
- Shape = (2,4)
- Size = 2*4 (2 row 4 cols) = 8
- Vector elements = 8 because 2D tensor contains 8 elements

? SOME INTERACTIVE QUE :

1. What is the rank and shape of a tensor storing 100 audio samples of 44,100 points each?
2. For an RGB video batch of size 10 with 20 frames of 128×128 pixels, what is the tensor rank and shape?
3. What is the difference between an array and a tensor conceptually?
4. Give a typical 5D tensor shape for videos.
5. Give two real-world examples of scalars.
6. **What does the shape of a tensor represent?**
7. **What is meant by an axis in a tensor?**
8. **What is the rank of a tensor with shape (32, 28, 28)?**
9. When do we use a 5D tensor?
10. **What is the rank and shape of 100 RGB images of size 64×64?**