# Artificial Models for Music Creativity

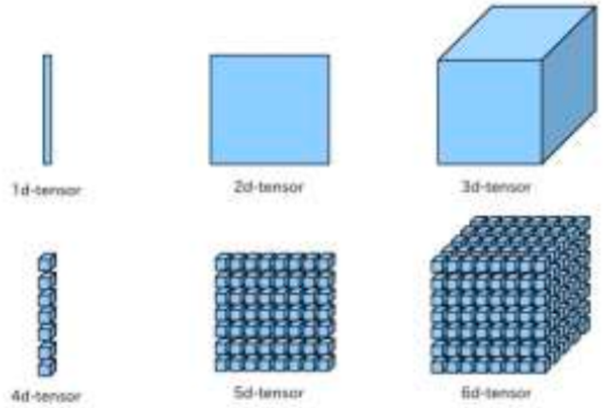
## Lesson 2 - Introduction to high-dimensional data structure

Artificial Models for Multimodal Creativity
Alessandro Anatrini - 8.11.2024

# Four Myths on Artificial Intelligence

1. Tensor: Dimension
2. Tensor: Shape
3. Real world data: Which tensor?

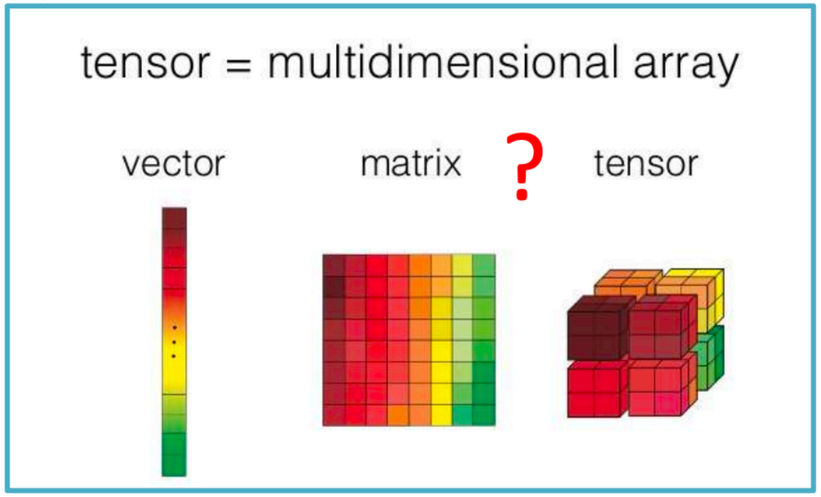
# WTF IS A TENSOR?

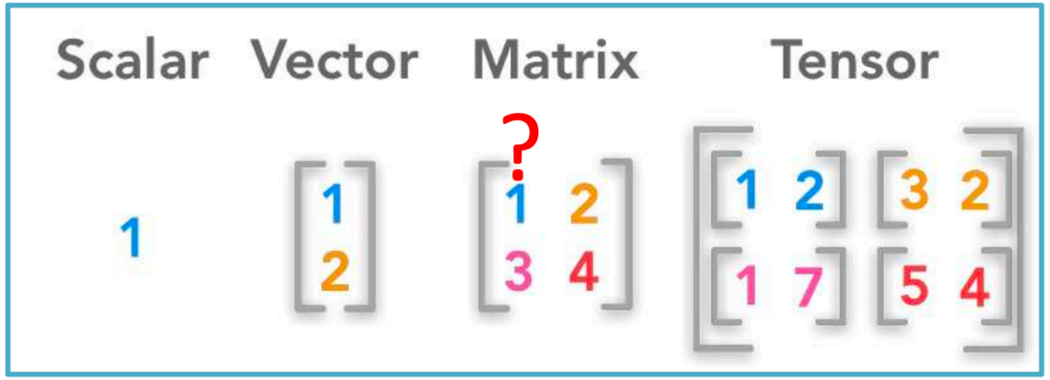



## A tensor is a container for data

## Data are almost numerical data

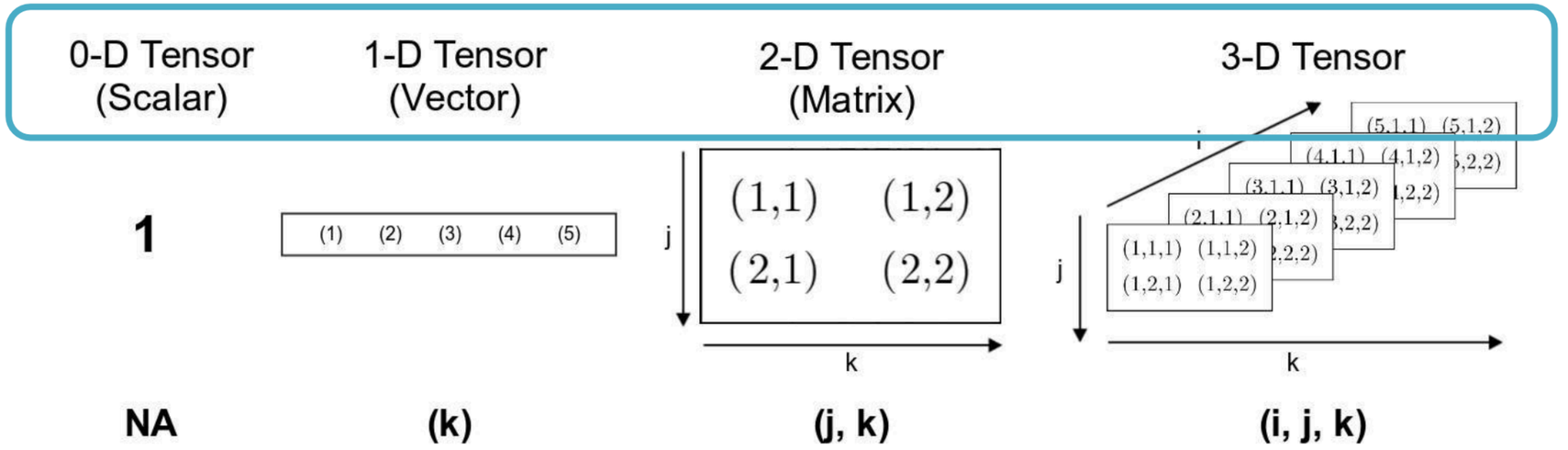
A tensor is a general name for a multi-way array data. 1d-tensor is a vector, 2d is a matrix, 3d is a cube. We can imagine a 4d-tensor as a vector of cubes, 5d as a matrix of cubes and 6d as a cube of cubes.



# KEYWORDS

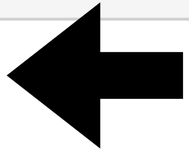
1. Generalisation of matrices to an arbitrary number of dimensions
2. In tensor dimension is often called axis
3. No. of dimensions (=axis) is called ranks



# Scalar - 0d tensor

A tensor that contains only one number is called scalar

```
In [1]: import numpy as np

In [2]: x = np.array(12)

In [3]: x
Out[3]: array(12)

In [4]: x.ndim
Out[4]: 0
```

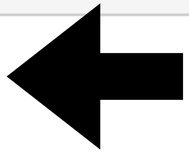


dimension can be shown using the **ndim** method

# Vector - 1d tensor

## An array of numbers is called vector or 1d tensor

```
In [1]: import numpy as np

In [5]: x = np.array([23, 45, 66, 2])

In [6]: x
Out[6]: array([23, 45, 66,  2])

In [7]: x.ndim
Out[7]: 1
```



# Matrix - 2d tensor

## An array of vectors is called matrix or 2d tensor

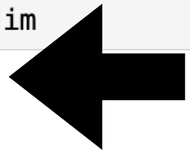
```
In [1]: import numpy as np

In [26]: x = np.array([[23, 45, 66, 2],
                       [12, 44, 31, 89],
                       [72, 49, 20 ,3]])

In [27]: x

Out[27]: array([[23, 45, 66,  2],
                [12, 44, 31, 89],
                [72, 49, 20,  3]])

In [28]: x.ndim

Out[28]: 2
```

# 3D TENSOR

From 3d-tensor on it is just

nd-tensor

```
In [1]: import numpy as np

In [12]: x = np.array([[[1, 3, 5, 7],
                        [2, 4, 6, 8],
                        [3, 6, 9, 12]],
                       [[1, 3, 5, 7],
                        [2, 4, 6, 8],
                        [3, 6, 9, 12]],
                       [[1, 3, 5, 7],
                        [2, 4, 6, 8],
                        [3, 6, 9, 12]]])

In [13]: x

Out[13]: array([[[ 1,  3,  5,  7],
                 [ 2,  4,  6,  8],
                 [ 3,  6,  9, 12]],

                [[ 1,  3,  5,  7],
                 [ 2,  4,  6,  8],
                 [ 3,  6,  9, 12]],

                [[ 1,  3,  5,  7],
                 [ 2,  4,  6,  8],
                 [ 3,  6,  9, 12]]])

In [14]: x.ndim

Out[14]: 3
```



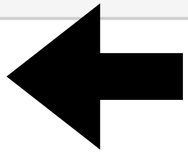
# 3D TENSOR

1. Number of dimensions (=axes)
2. Shape: how many dimensions the tensor has along each axis
3. Data type: dtype in python (float32, float64, unit8...)
4. Shape is a key element in DL programming

# Scalar - 0d tensor

## Scalar has empty shape

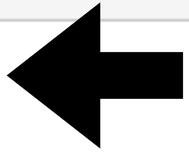
```
In [1]: import numpy as np

In [17]: x = np.array(3)

In [18]: x.ndim
Out[18]: 0

In [19]: x.shape
Out[19]: ()
```



# Vector - 1d tensor

## 1d tensor has a shape with a single element

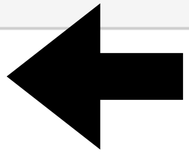
```
In [1]: import numpy as np

In [20]: x = np.array([23, 45, 66, 2])

In [21]: x.ndim
Out[21]: 1

In [22]: x.shape
Out[22]: (4,)
```



# Vector - 1d tensor

## 2d tensor is a matrix

```
In [1]: import numpy as np

In [23]: x = np.array([[23, 45, 66, 2],
                       [12, 44, 31, 89],
                       [72, 49, 20 ,3]])

In [24]: x.ndim

Out[24]: 2

In [25]: x.shape

Out[25]: (3, 4)
```



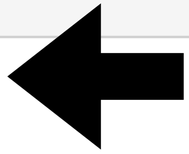
# 3D TENSOR

a 3d tensor's shape

is represented with

3 numbers

```
In [1]: import numpy as np

In [12]: x = np.array([[[1, 3, 5, 7],
                        [2, 4, 6, 8],
                        [3, 6, 9, 12]],
                       [[1, 3, 5, 7],
                        [2, 4, 6, 8],
                        [3, 6, 9, 12]],
                       [[1, 3, 5, 7],
                        [2, 4, 6, 8],
                        [3, 6, 9, 12]]])

In [15]: x.ndim

Out[15]: 3

In [16]: x.shape

Out[16]: (3, 3, 4)
```



# SUMMARY

| dimension | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| name | scalar | vector | matrix | 3d tensor | 4d tensor |
| aka | 0d tensor | 1d tensor | 2d tensor | 3d tensor | 4d tensor |
| example | 12 | [23, 45, 66, 2] | [[23, 45, 66, 2],<br>[12, 44, 31, 89],<br>[72, 49, 20, 3]] | [[[1, 3, 5, 7],<br>[2, 4, 6, 8],<br>[3, 6, 9, 12]],<br>[[1, 3, 5, 7],<br>[2, 4, 6, 8],<br>[3, 6, 9, 12]],<br>[[1, 3, 5, 7],<br>[2, 4, 6, 8],<br>[3, 6, 9, 12]]] | … |
| shape | () | (4) | (3,4) | (3, 3, 4) | (5, 3, 3, 4) |

# Real World examples

| Name | Tensor | Shape |
|---|---|---|
| Vector data* | 2D tensor | (samples, feature) |
| Timeseries data or sequence data | 3D tensor | (samples, timesteps, features) |
| Images | 4D tensor | (samples, height, width, channels) |
| Video | 5D tensor | (samples, frames, height, width, channels) |

# Real World examples

## 2d tensor: actual personal data

3

| Samples | Age | ZIP code | Income |
|---|---|---|---|
| 1 | 12 | 123-324 | 10k |
| 2 | 34 | 234-567 | 13k |
| 3 | 12 | 349-874 | 20k |
| … | | | |
| | | | |
| 9,999 | 45 | 874-988 | 30k |
| 10,000 | 56 | 888-234 | 12k |

10,000

- Numpy array

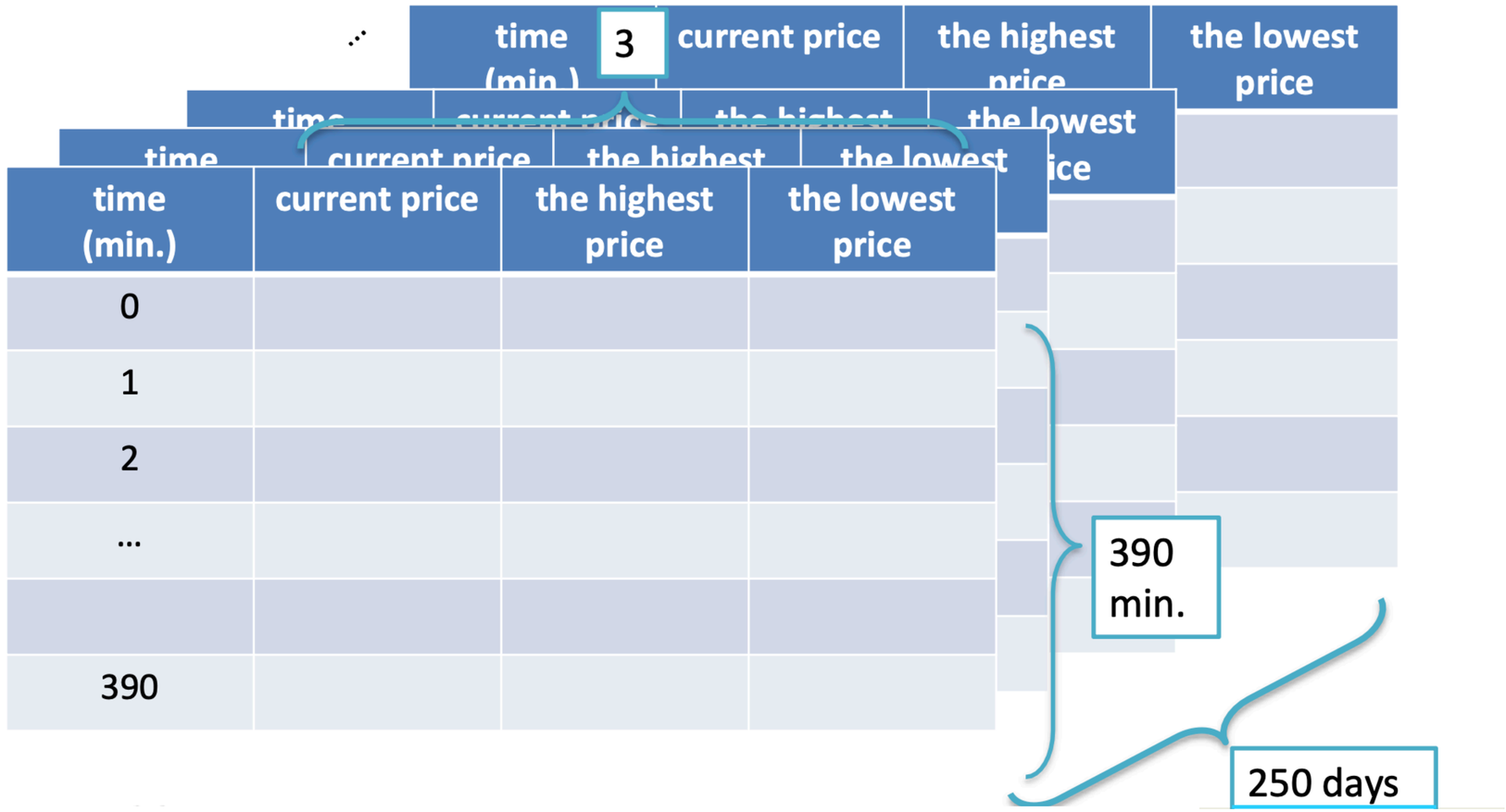
[[12, 123-324,10k],
[34,234-567,13k],
…
[56 ,888-234, 12k]]

Shape (samples, features) = (10000, 3)

# Real World examples

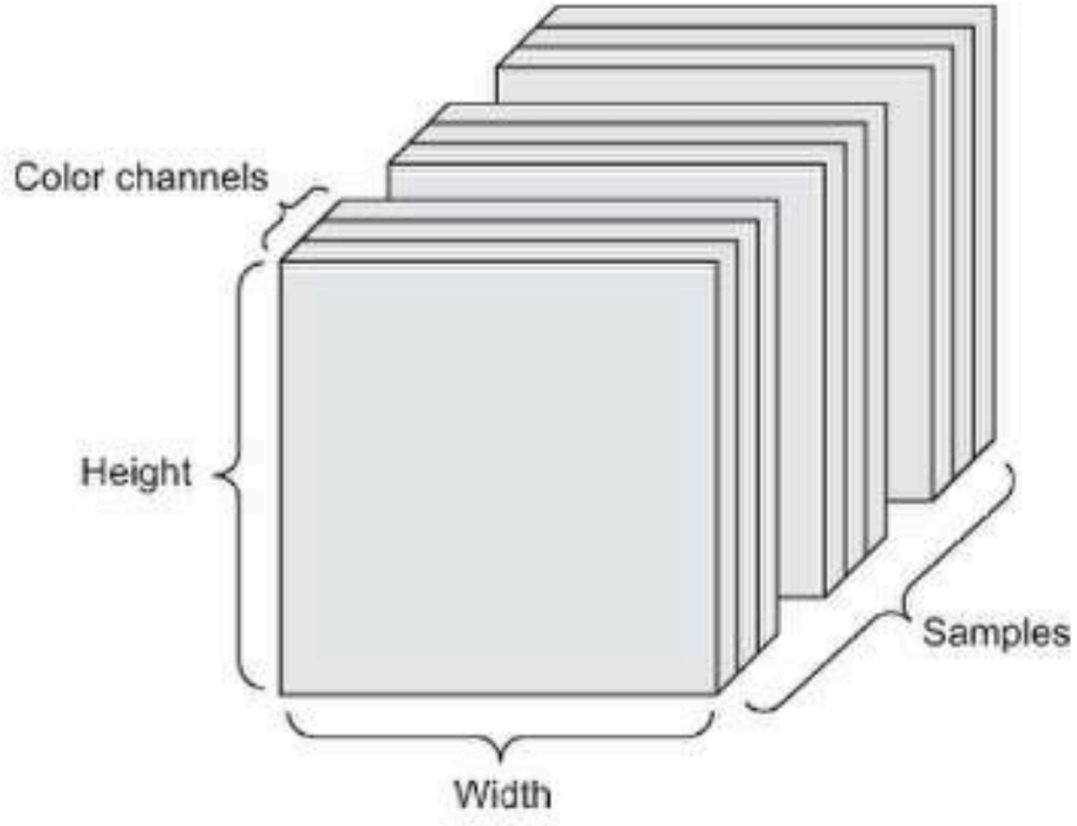
## 3d tensor: stock price dataset

Shape (samples, time steps, features) = (250, 390, 3)



# Real World examples

4d tensor: a batch of 128 colour images of size 256*256




Shape (samples, height, width, channels) = (128, 256, 256, 3)

# Real World examples

5d tensor: 60 sec, 144*156 Yt video clip at 4 fps would be 240 frames. A batch of 4 such video clips

Shape (samples, frames, height, width, channels) = (4, 240, 144, 156, 3)

Total = 4*240*144*156*3 = 106.168.320
if type of tensor is float32, total memory will be about 405 MB