Artificial Models for Music Creativity

Lesson 3 - Focus on Neural Networks

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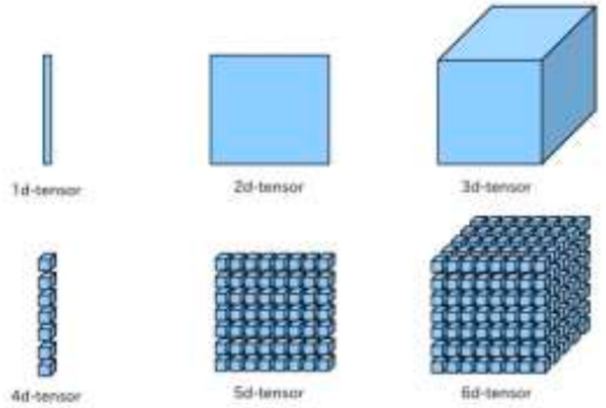
AGENDA HF MT HAMBURG

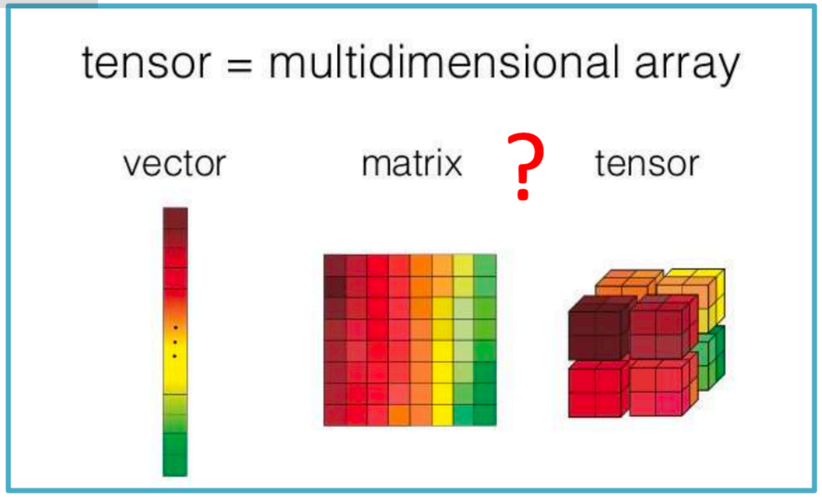
WTF IS A TENSOR?

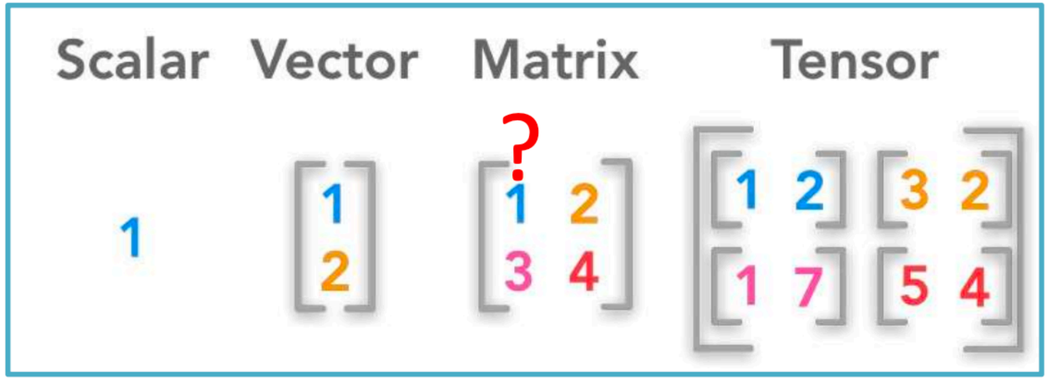


A tensor is a container for data

Data are almost numerical data

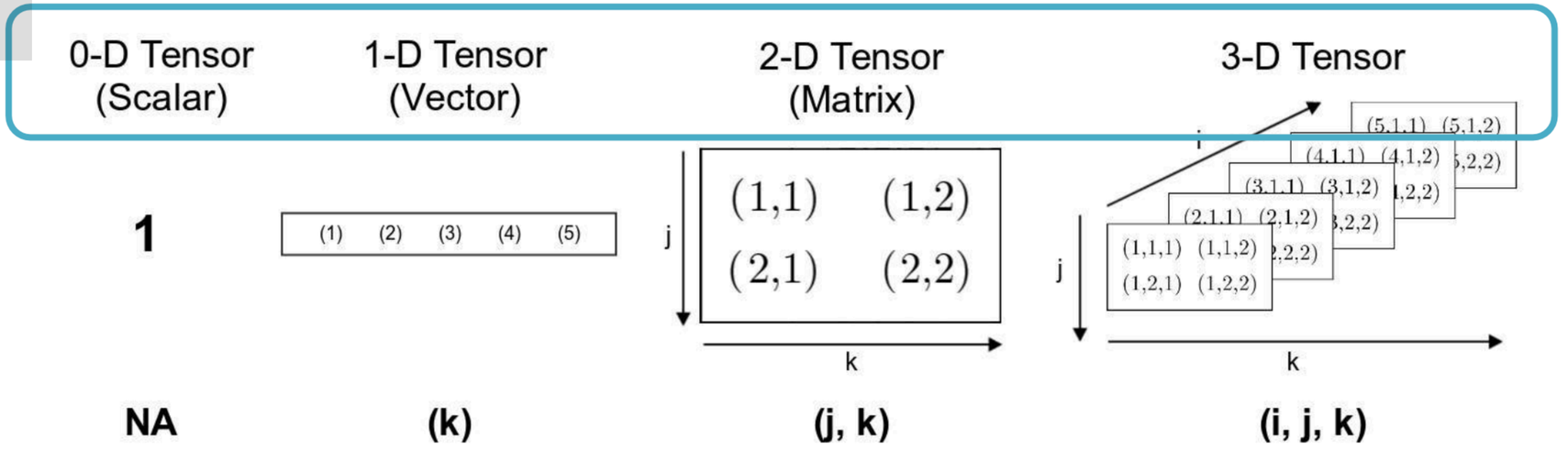
A tensor is a general name for a multi-way array data. 1d-tensor is a vector, 2d is a matrix, 3d is a cube. We can imagine a 4d-tensor as a vector of cubes, 5d as a matrix of cubes and 6d as a cube of cubes.





KEYWORDS

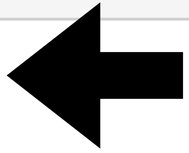
1. Generalisation of matrices to an arbitrary number of dimensions
2. In tensor dimension is often called axis
3. No. of dimensions (=axis) is called ranks



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
```

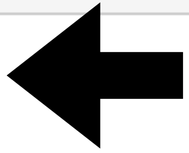


dimension can be shown using the `ndim` method

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

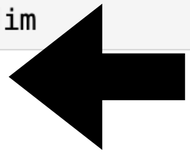
An array of vectors is called matrix or 2d tensor

```
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

2

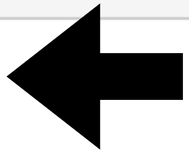
1. Number of dimensions (=axes)
2. Shape: how many dimensions the tensor has along each axis
3. Data type: dtype in python (float32, float64, unit8…)
4. Shape is a key element in DL programming

SCALAR - 0D TENSOR

2

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]: ()
```

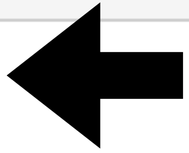


VECTOR - 1D TENSOR

2

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,)
```

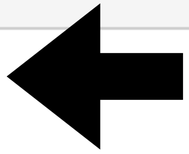


VECTOR - 1D TENSOR

2

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], [12, 44, 31, 89], [72, 49, 20, 3]]	[[[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]]]	...
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

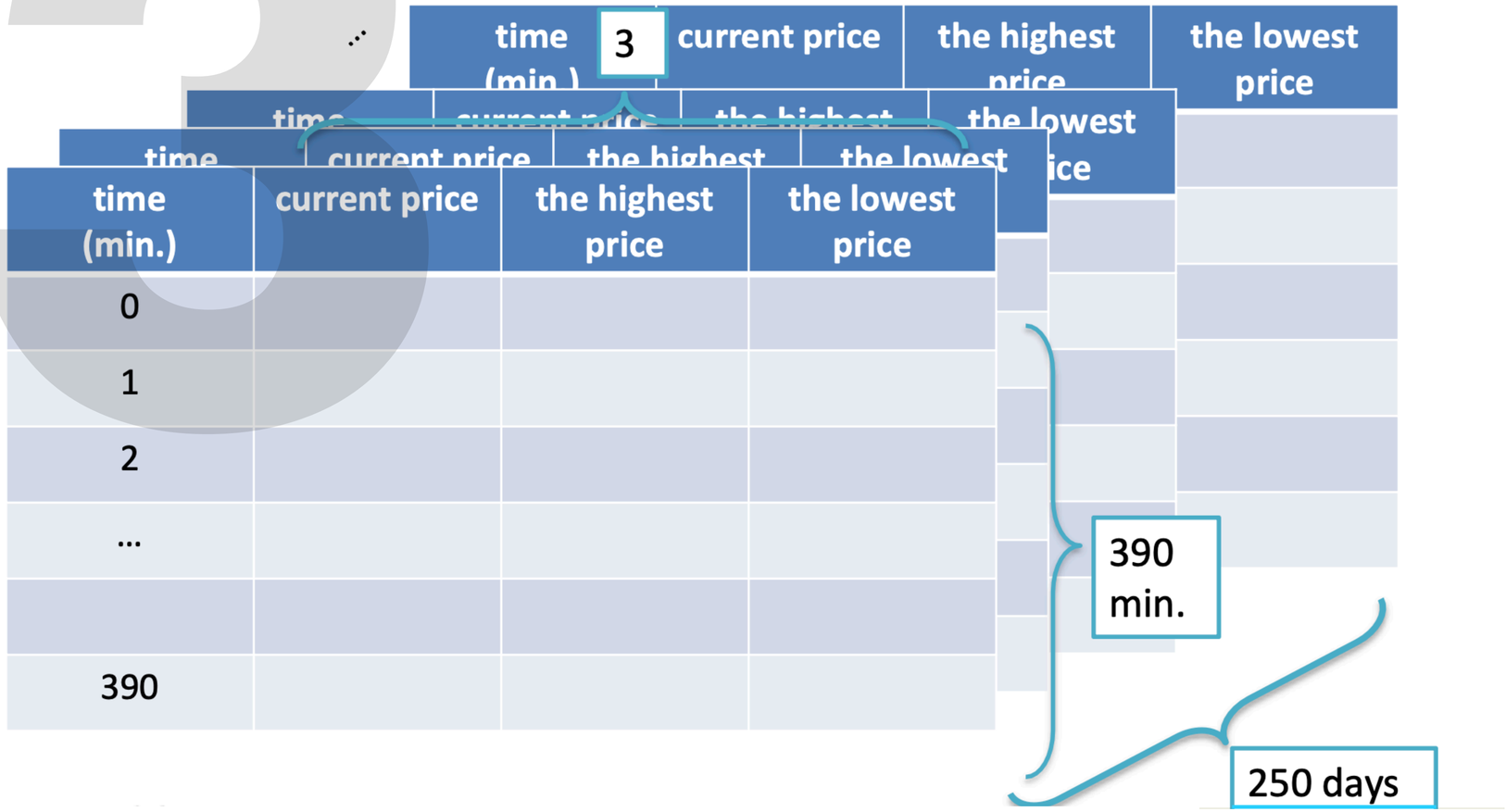
[[12, 123-324,10k],
[34,234-567,13k],
…
[56 ,888-234, 12k]]

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

Real World examples

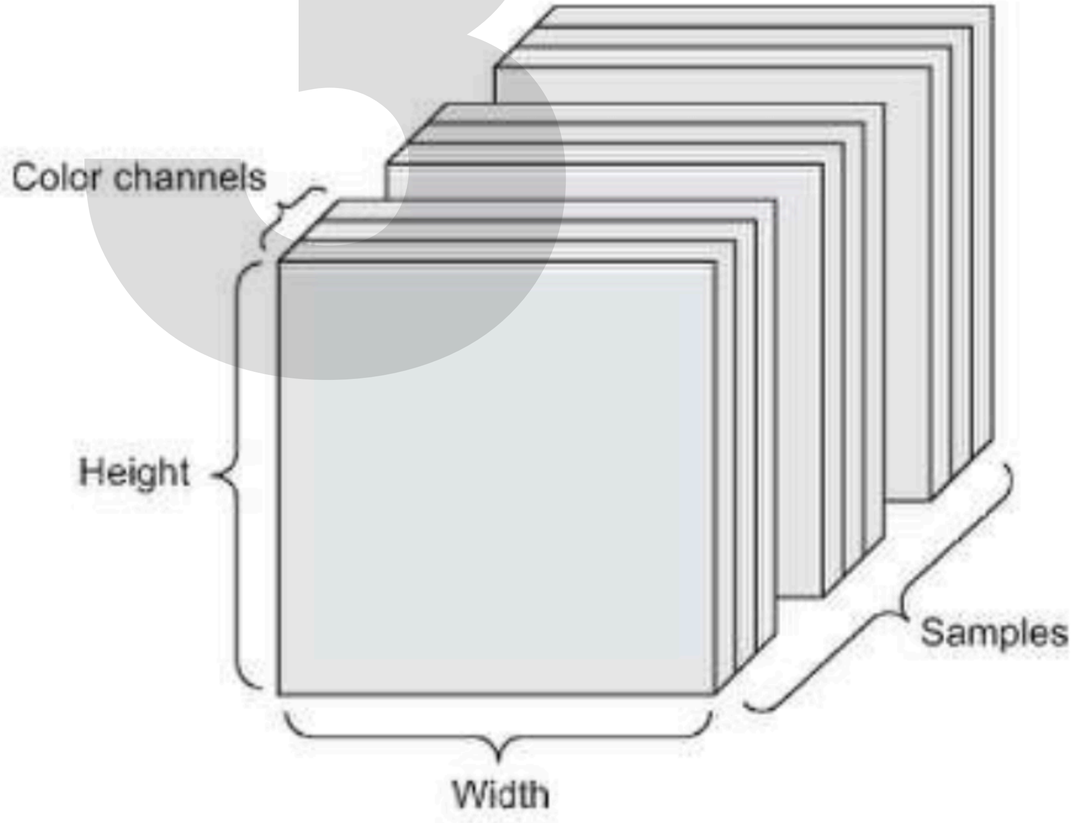
3d tensor: stock price dataset

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