Basics of Tensors

Curiculum

1. Core data structure
2. Tensor Creation
3. Getting information from tensors

1. Core data structure (Scalars, Vector, Matrices)

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Scalars can be considered as a rank-0-tensor. Let's denote scalar value as $x \in \mathbb{R}$, where $\mathbb{R}$ is a set of real numbers.

Vectors can be introduced as a rank-1-tensor. Vectors belong to linear space (vector space), which is, in simple terms, a set of possible vectors of a specific length. A vector consisting of real-valued scalars ($x \in \mathbb{R}$) can be defined as ($y \in \mathbb{R}^n$), where y - vector value and $\mathbb{R}^n$ - n-dimensional real-number vector space. y_i - i_{th} vector element (scalar):

$$y = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}$$

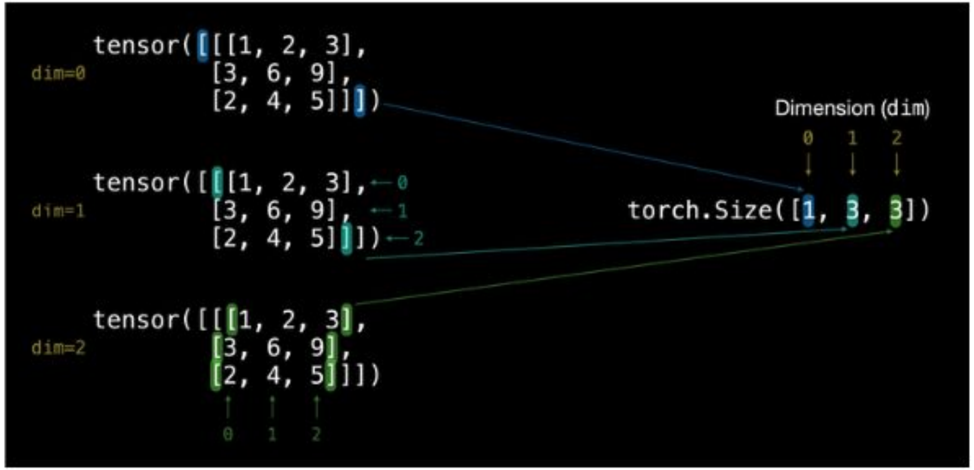
Matrices can be considered as a rank-2-tensor. A matrix of size $m \times n$, where $m, n \in \mathbb{N}$ (rows and columns number accordingly) consisting of real-valued scalars can be denoted as $A \in \mathbb{R}^{m \times n}$, where $\mathbb{R}^{m \times n}$ is a real-valued $m \times n$-dimensional vector space:

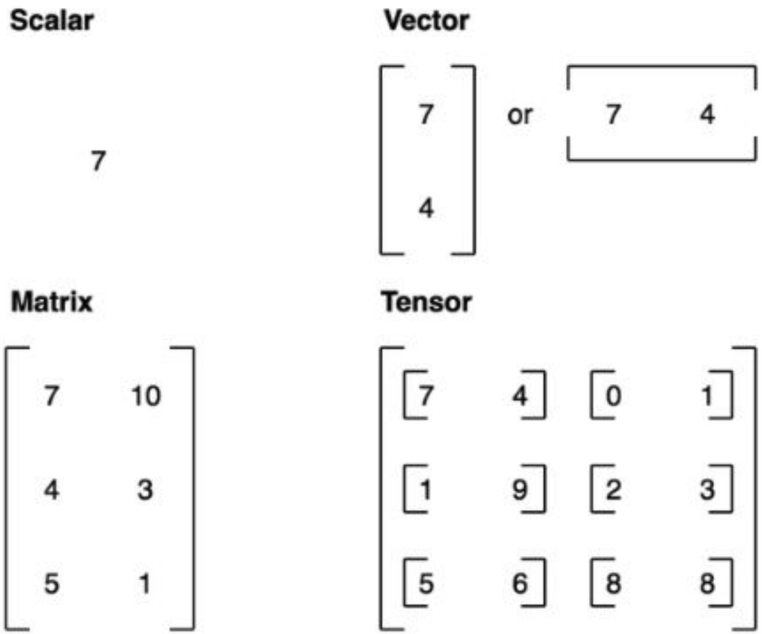
$$A = \begin{bmatrix} x_{11} & x_{12} & x_{13} & \dots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \dots & x_{mn} \end{bmatrix}$$

Tensor is an entity with a defined number of dimensions called an order **(rank)**.

Scalar = a single number and in tensor-speak it's a zero dimension tensor.

1. Core data structure (Scalars, Vector, Matrices)





Note: You might've noticed me using lowercase letters for `scalar` and `vector` and uppercase letters for `MATRIX` and `TENSOR`. This was on purpose. In practice, you'll often see scalars and vectors denoted as lowercase letters such as `y` or `a`. And matrices and tensors denoted as uppercase letters such as `X` or `W`.

You also might notice the names martrix and tensor used interchangably. This is common. Since in PyTorch you're often dealing with `torch.Tensor`'s (hence the tensor name), however, the shape and dimensions of what's inside will dictate what it actually is.

1. Core data structure (Scalars, Vector, Matrices)

```python
matrix = torch.tensor([[7, 8],
                       [9, 10]])

print(matrix.ndim)
print(matrix.shape)
```

✓ 0.0s

```
2
torch.Size([2, 2])
```

```python
tensor = torch.tensor([[[1,2,3],
                        [4, 5, 6],
                        [2, 4 ,5]]])
print(tensor.ndim)
print(tensor.shape)
```

✓ 0.0s

```
3
torch.Size([1, 3, 3])
```

- You can tell the **number of dimensions** a tensor in PyTorch has by the number of square brackets on the outside and you only need to count one side
- Another important concept for tensors is their **shape attribute**. **The shape tells you how the elements inside them are arranged.**

2. Tensor Creation

2. Tensor Creation and Numpy interoperability

```python
empty = torch.empty(size=(3, 3))  # Tensor of shape 3x3 with uninitialized data
zeros = torch.zeros(size=(3, 4))
ones = torch.ones(size=(3, 4))
rand = torch.rand((3, 3))  # Tensor of shape 3x3 with values from uniform distribution in interval [0,1)
eye = torch.eye(5, 5)  # Returns Identity Matrix I, (I <-> Eye), matrix of shape 2x3
arange = torch.arange(start=0, end=5, step=1)  # Tensor [0, 1, 2, 3, 4], note, can also do: torch.arange(11)
linspace = torch.linspace(start=0.1, end=1, steps=10)  # x = [0.1, 0.2, ..., 1]
```

```python
print(empty, empty.dtype, empty.shape)
print(zeros, zeros.dtype, zeros.shape)
print(ones, ones.dtype, ones.shape)
print(rand, rand.dtype, rand.shape)
print(eye, eye.dtype, eye.shape)
print(arange, arange.dtype, arange.shape)
print(linspace, linspace.dtype, linspace.shape)
```

0.0s

```
tensor([[0., 0., 0.],
        [0., 0., 0.],
        [0., 0., 0.]]) torch.float32 torch.Size([3, 3])
tensor([[0., 0., 0., 0.],
        [0., 0., 0., 0.],
        [0., 0., 0., 0.]]) torch.float32 torch.Size([3, 4])
tensor([[1., 1., 1., 1.],
        [1., 1., 1., 1.],
        [1., 1., 1., 1.]]) torch.float32 torch.Size([3, 4])
tensor([[0.7787, 0.1542, 0.4201],
        [0.9481, 0.1338, 0.7235],
        [0.2711, 0.6595, 0.4061]]) torch.float32 torch.Size([3, 3])
tensor([[1., 0., 0., 0., 0.],
        [0., 1., 0., 0., 0.],
        [0., 0., 1., 0., 0.],
        [0., 0., 0., 1., 0.],
        [0., 0., 0., 0., 1.]]) torch.float32 torch.Size([5, 5])
tensor([0, 1, 2, 3, 4]) torch.int64 torch.Size([5])
tensor([0.1000, 0.2000, 0.3000, 0.4000, 0.5000, 0.6000, 0.7000, 0.8000, 0.9000,
        1.0000]) torch.float32 torch.Size([10])
```

2. Tensor Creation and Numpy interoperability

```python
# How to make initialized tensors to other types (int, float, double)
# These will work even if you're on CPU or CUDA!
tensor = torch.arange(4)  # [0, 1, 2, 3] Initialized as int64 by default
print(f"Converted Boolean: {tensor.bool()}")  # Converted to Boolean: 1 if nonzero
print(f"Converted int16 {tensor.short()}")  # Converted to int16
print(
    f"Converted int64 {tensor.long()}"
)  # Converted to int64 (This one is very important, used super often)
print(f"Converted float16 {tensor.half()}")  # Converted to float16
print(
    f"Converted float32 {tensor.float()}"
)  # Converted to float32 (This one is very important, used super often)
print(f"Converted float64 {tensor.double()}")  # Converted to float64$
```

✓ 0.0s

```
Converted Boolean: tensor([False,  True,  True,  True])
Converted int16 tensor([0, 1, 2, 3], dtype=torch.int16)
Converted int64 tensor([0, 1, 2, 3])
Converted float16 tensor([0., 1., 2., 3.], dtype=torch.float16)
Converted float32 tensor([0., 1., 2., 3.])
Converted float64 tensor([0., 1., 2., 3.], dtype=torch.float64)
```

3. Getting Information from tensors

3. Getting information from tensors

```
some_tensor = torch.rand(3, 4)

# Find out details about it
print(some_tensor)
print(f"Shape of tensor: {some_tensor.shape}")
print(f"Datatype of tensor: {some_tensor.dtype}")
print(f"Device tensor is stored on: {some_tensor.device}") # will default to CPU
```

[28] ✓ 0.0s

```
tensor([[0.2786, 0.0116, 0.5478, 0.3113],
        [0.9064, 0.6342, 0.8010, 0.2864],
        [0.6679, 0.6846, 0.7372, 0.5038]])
Shape of tensor: torch.Size([3, 4])
Datatype of tensor: torch.float32
Device tensor is stored on: cpu
```

- **shape** - what shape is the tensor? (some operations require specific shape rules)
- **dtype** - what datatype are the elements within the tensor stored in?
- **device** - what device is the tensor stored on? (usually GPU or CPU)

Note: When you run into issues in PyTorch, it's very often one to do with one of the three attributes above. So when the error messages show up, sing yourself a little song called "what, what, where":
"what shape are my tensors? what datatype are they and where are they stored? what shape, what datatype, where where where"