Deep learning

1.6. Tensor internals

François Fleuret

https://fleuret.org/dlc/

Nov 24, 2020
A tensor is a view of a [part of a] storage, which is a low-level 1d vector.

```python
>>> x = torch.zeros(2, 4)
>>> x.storage()
 0.0
 0.0
 0.0
 0.0
 0.0
 0.0
 0.0
 0.0
 0.0
 0.0
 0.0
 0.0
 0.0
 0.0
 0.0
 [torch.FloatStorage of size 8]
>>> q = x.storage()
>>> q[4] = 1.0
>>> x
tensor([[ 0.,  0.,  0.,  0.],
         [ 1.,  0.,  0.,  0.]])
```
Multiple tensors can share the same storage. It happens when using operations such as view(), expand() or transpose().

```python
>>> y = x.view(2, 2, 2)
>>> y
tensor([[ 0.,  0.],
         [ 0.,  0.]],
        [[ 1.,  0.],
         [ 0.,  0.]]))
>>> y[1, 1, 0] = 7.0
>>> x
tensor([[ 0.,  0.,  0.,  0.],
         [ 1.,  0.,  7.,  0.]]))
>>> y.narrow(0, 1, 1).fill_(3.0)
tensor([[ 3.,  3.],
         [ 3.,  3.]]))
```
The first coefficient of a tensor is the one at `storage_offset()` in `storage()`.
The first coefficient of a tensor is the one at `storage_offset()` in `storage()`.

Incrementing index \( k \) by 1 move by `stride(k)` elements in the storage.
The first coefficient of a tensor is the one at `storage_offset()` in `storage()`.

Incrementing index $k$ by 1 move by `stride(k)` elements in the storage.

```python
>>> q = torch.arange(0, 20).storage()
>>> x = torch.empty(0).set_(q, storage_offset = 5, size = (3, 2), stride = (4, 1))
>>> x
tensor([[ 5.,  6.],
        [ 9., 10.],
        [13., 14.]])
```
The first coefficient of a tensor is the one at `storage_offset()` in `storage()`.

Incrementing index $k$ by 1 move by `stride(k)` elements in the storage.

```python
>>> q = torch.arange(0, 20).storage()
>>> x = torch.empty(0).set_(q, storage_offset = 5, size = (3, 2), stride = (4, 1))
>>> x
tensor([[ 5.,  6.],
        [ 9., 10.],
        [13., 14.]])
```

$q =$

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
The first coefficient of a tensor is the one at `storage_offset()` in `storage()`.

Incrementing index $k$ by 1 move by `stride(k)` elements in the storage.

```python
>>> q = torch.arange(0, 20).storage()
>>> x = torch.empty(0).set_(q, storage_offset = 5, size = (3, 2), stride = (4, 1))
>>> x
tensor([[ 5.,  6.],
        [ 9., 10.],
        [13., 14.]])
```

$q =$

```
      0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19
   x[0,0] x[0,1] x[1,0] x[1,1] x[2,0] x[2,1]
```
The first coefficient of a tensor is the one at `storage_offset()` in `storage()`.

Incrementing index $k$ by 1 move by `stride(k)` elements in the storage.

```python
g = torch.arange(0, 20).storage()
x = torch.empty(0).set_(g, storage_offset = 5, size = (3, 2), stride = (4, 1))
x
```
```
tensor([[ 5.,  6.],
          [ 9., 10.],
          [13., 14.]])
```
The first coefficient of a tensor is the one at `storage_offset()` in `storage()`.

Incrementing index $k$ by 1 move by `stride(k)` elements in the storage.

```python
>>> q = torch.arange(0, 20).storage()
>>> x = torch.empty(0).set_(q, storage_offset = 5, size = (3, 2), stride = (4, 1))
```

```
tensor([[ 5.,  6.],
         [ 9., 10.],
         [13., 14.]])
```
The first coefficient of a tensor is the one at `storage_offset()` in `storage()`.

Incrementing index $k$ by 1 move by `stride(k)` elements in the storage.

```python
>>> q = torch.arange(0, 20).storage()
>>> x = torch.empty(0).set_(q, storage_offset = 5, size = (3, 2), stride = (4, 1))
>>> x
tensor([[ 5.,  6.],
        [ 9., 10.],
        [13., 14.]]
```
We can explicitly create different “views” of the same storage

```python
>>> n = torch.linspace(1, 4, 4)
>>> n
tensor([ 1., 2., 3., 4.])
>>> torch.tensor(0.).set_(n.storage(), 1, (3, 3), (0, 1))
tensor([[ 2., 3., 4.],
        [ 2., 3., 4.],
        [ 2., 3., 4.]])
>>> torch.tensor(0.).set_(n.storage(), 1, (2, 4), (1, 0))
tensor([[ 2., 2., 2., 2.],
        [ 3., 3., 3., 3.]])
```
We can explicitly create different “views” of the same storage

```python
>>> n = torch.linspace(1, 4, 4)
>>> n
tensor([ 1.,  2.,  3.,  4.])
>>> torch.tensor(0.).set_(n.storage(), 1, (3, 3), (0, 1))
tensor([[ 2.,  3.,  4.],
        [ 2.,  3.,  4.],
        [ 2.,  3.,  4.]])
>>> torch.tensor(0.).set_(n.storage(), 1, (2, 4), (1, 0))
tensor([[ 2.,  2.,  2.,  2.],
        [ 3.,  3.,  3.,  3.]])
```

This is in particular how transpositions and broadcasting are implemented.

```python
>>> x = torch.empty(100, 100)
>>> x.stride()
(100, 1)
>>> y = x.t()
>>> y.stride()
(1, 100)
```
This organization explains the following (maybe surprising) error

```python
>>> x = torch.empty(100, 100)
>>> x.t().view(-1)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
RuntimeError: invalid argument 2: view size is not compatible with input tensor's size and stride (at least one dimension spans across two contiguous subspaces). Call .contiguous() before .view()
```

`x.t()` shares `x`'s storage and cannot be “flattened” to 1d.
This organization explains the following (maybe surprising) error

```python
>>> x = torch.empty(100, 100)
>>> x.t().view(-1)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
RuntimeError: invalid argument 2: view size is not compatible with input tensor's size and stride (at least one dimension spans across two contiguous subspaces). Call .contiguous() before .view()
```

`x.t()` shares `x`'s storage and cannot be “flattened” to 1d.

This can be fixed with `contiguous()`, which returns a contiguous version of the tensor, **making a copy if needed.**

The function `reshape()` combines `view()` and `contiguous()`. 
The end