Deep learning

1.6. Tensor internals

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https://fleuret.org/ee559/

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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
[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 \texttt{view()}, \texttt{expand()} or \texttt{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.]]))
>>> x
tensor([[ 0.,  0.,  0.,  0.],
         [ 3.,  3.,  3.,  3.]]))
```
The first coefficient of a tensor is the one at `storage_offset()` in `storage()`.
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Incrementing index $k$ by 1 move by `stride(k)` elements in the storage.
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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.]])
```
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>>> q = torch.arange(0, 20).storage()
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>>> x
tensor([[ 5.,  6.],
        [ 9., 10.],
        [13., 14.]])
```

$q = \begin{bmatrix}
0 & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19
\end{bmatrix}$
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 tensor([[ 5.,  6.],
         [ 9., 10.],
         [13., 14.]]))
```

```
q =

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td>x[0,0]</td>
<td>x[0,1]</td>
<td>x[1,0]</td>
<td>x[1,1]</td>
<td>x[2,0]</td>
<td>x[2,1]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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</tr>
</tbody>
</table>
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>>> x = torch.empty(0).set_(q, storage_offset = 5, size = (3, 2), stride = (4, 1))
>>> x
    tensor([[ 5.,  6.],
            [ 9., 10.],
            [13., 14.]])
```

```
q =

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
</tr>
</thead>
</table>

offset

x[0,0]  x[0,1]

x[1,0]  x[1,1]

x[2,0]  x[2,1]
```
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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.]]))
```
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>>> q = torch.arange(0, 20).storage()
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```

Francois Fleuret
Deep learning / 1.6. Tensor internals
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

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>>> 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.
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Traceback (most recent call last):
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```

`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