

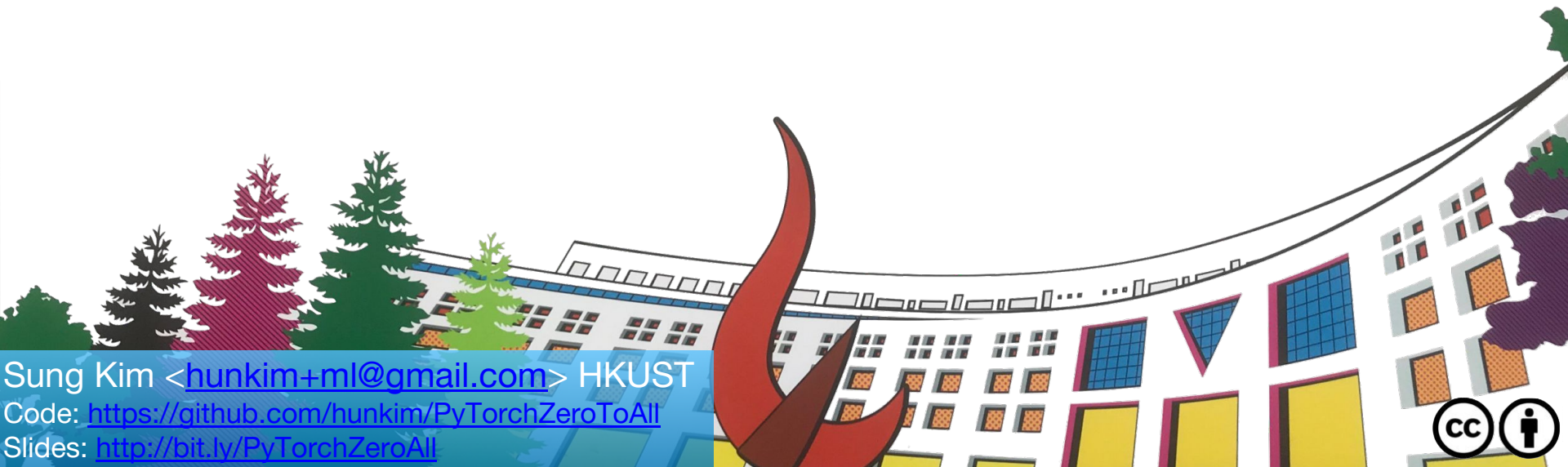
ML/DL for Everyone with PYTORCH

Lecture 10: CNN

Sung Kim <hunkim+ml@gmail.com> HKUST

Code: <https://github.com/hunkim/PyTorchZeroToAll>

Slides: <http://bit.ly/PyTorchZeroAll>



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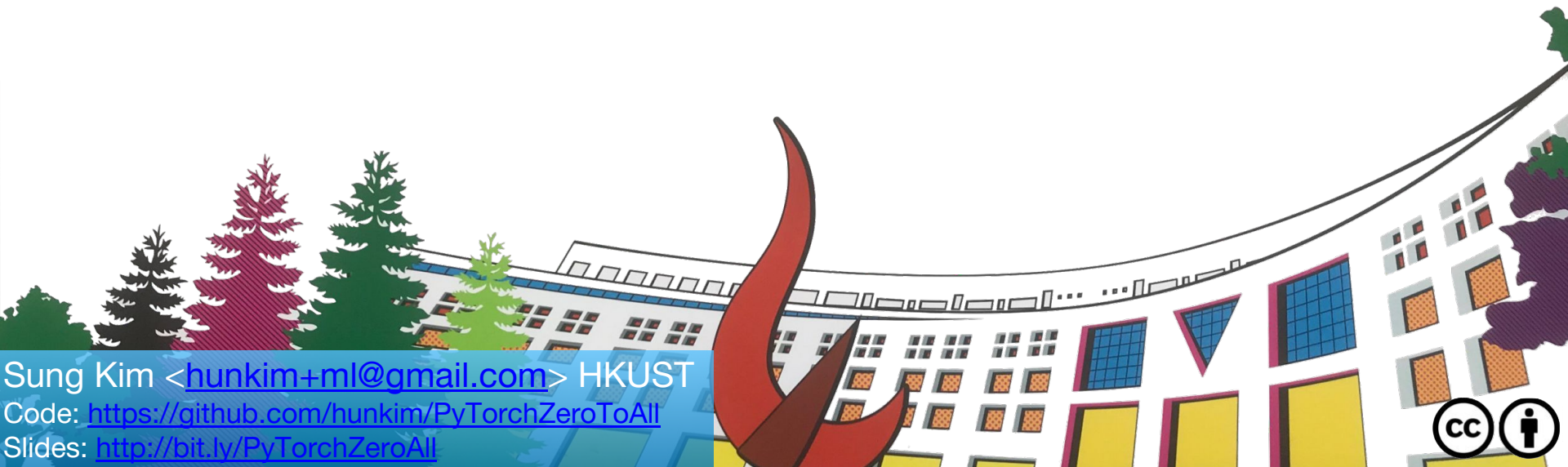
ML/DL for Everyone with PYTORCH

Lecture 10: CNN

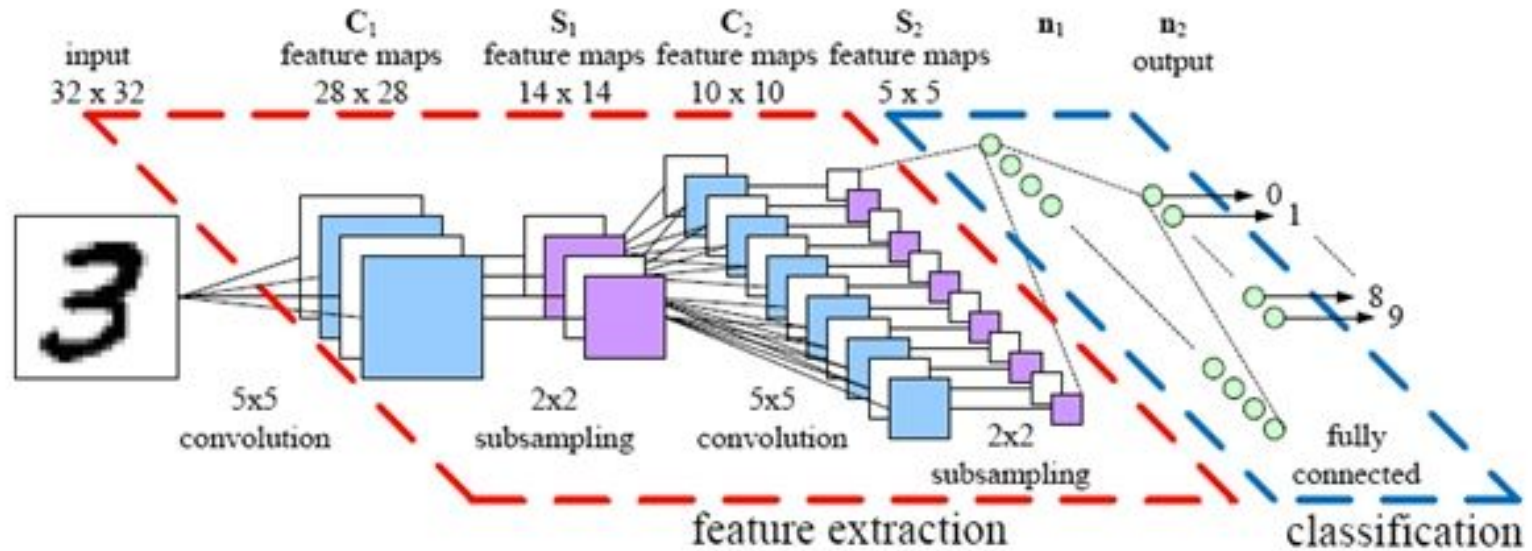
Sung Kim <hunkim+ml@gmail.com> HKUST

Code: <https://github.com/hunkim/PyTorchZeroToAll>

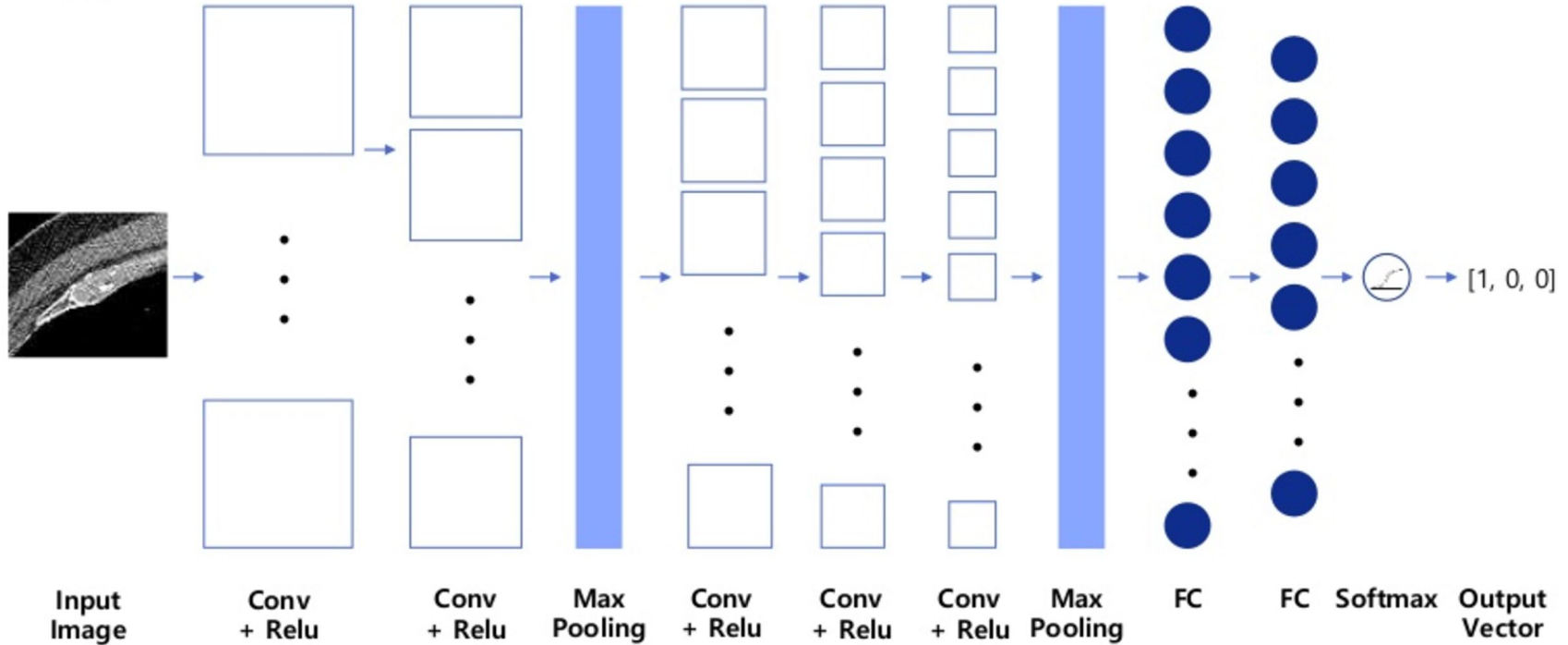
Slides: <http://bit.ly/PyTorchZeroAll>



CNN



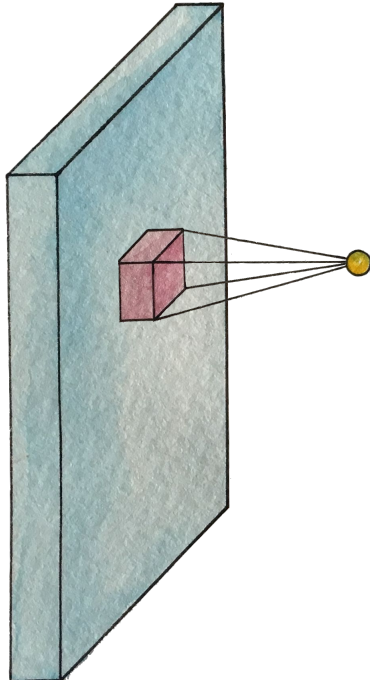
CNN for CT images



Asan Medical Center & Microsoft Medical Bigdata Contest Winner by GeunYoung Lee and Alex Kim

<https://www.slideshare.net/GYLee3/ss-72966495>

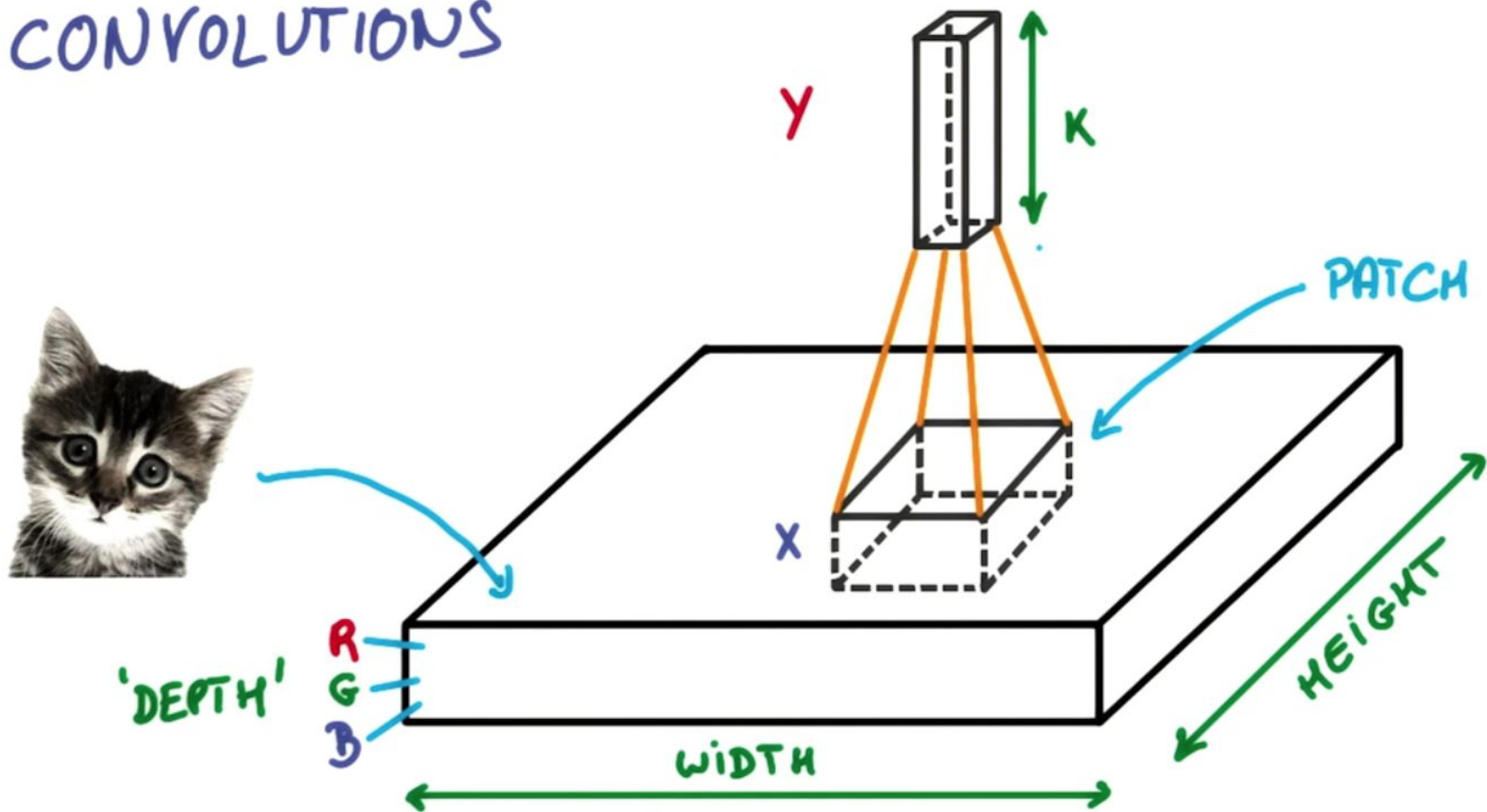
Convolution layer and max pooling



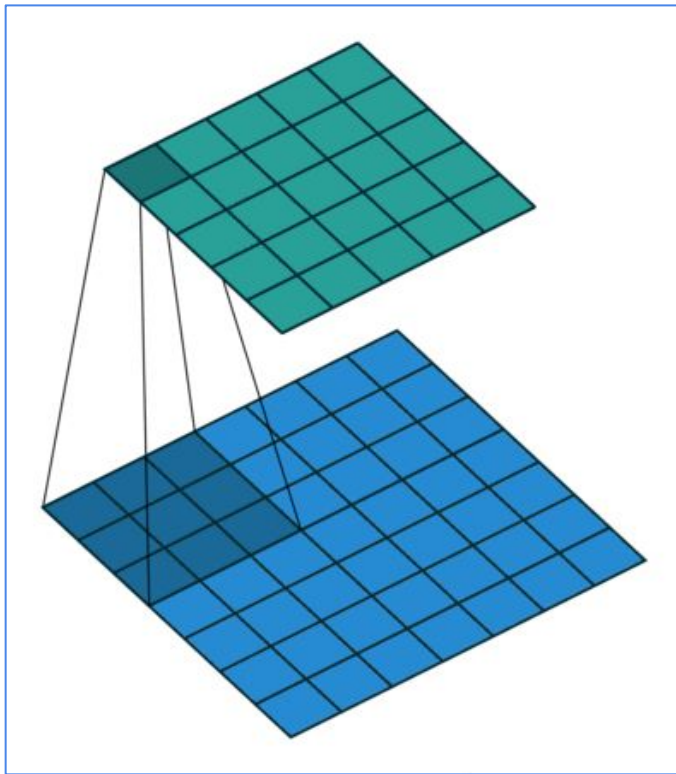
Single depth slice

| | | | |
|---|---|---|---|
| 1 | 1 | 2 | 4 |
| 5 | 6 | 7 | 8 |
| 3 | 2 | 1 | 0 |
| 1 | 2 | 3 | 4 |

CONVOLUTIONS

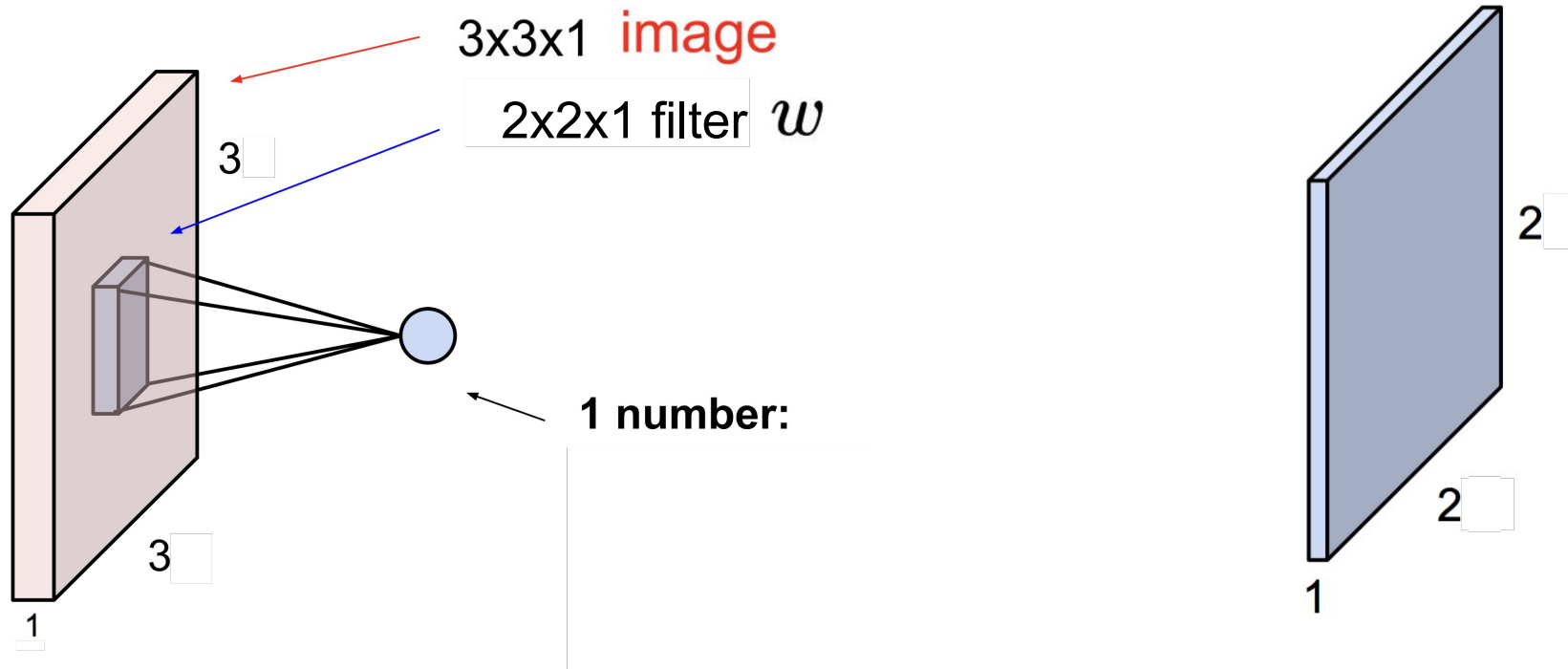


Convolution in Action



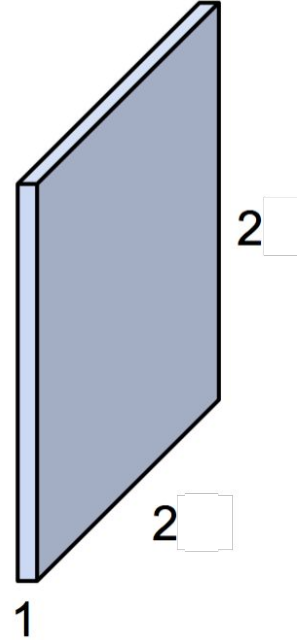
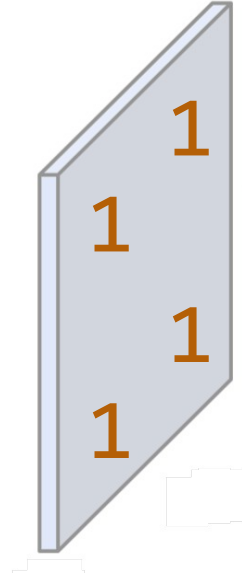
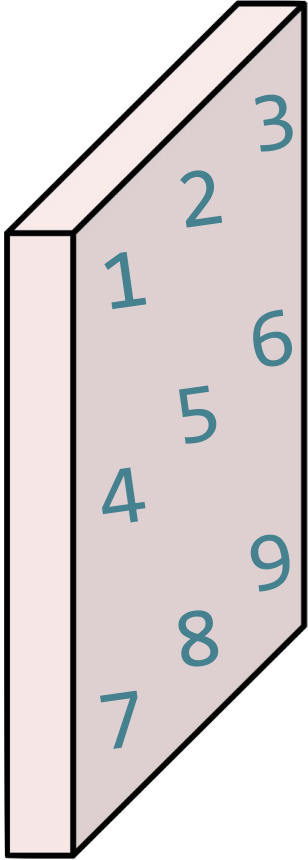
Simple convolution layer

Stride: 1x1



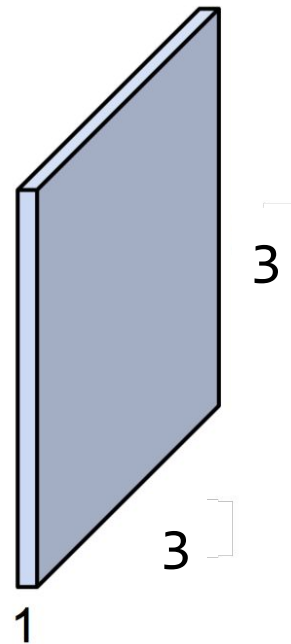
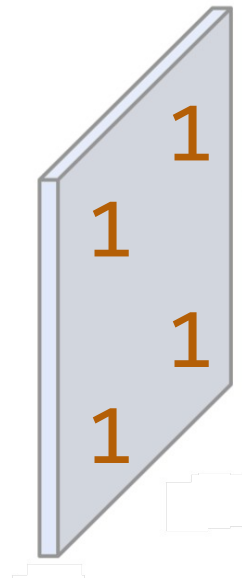
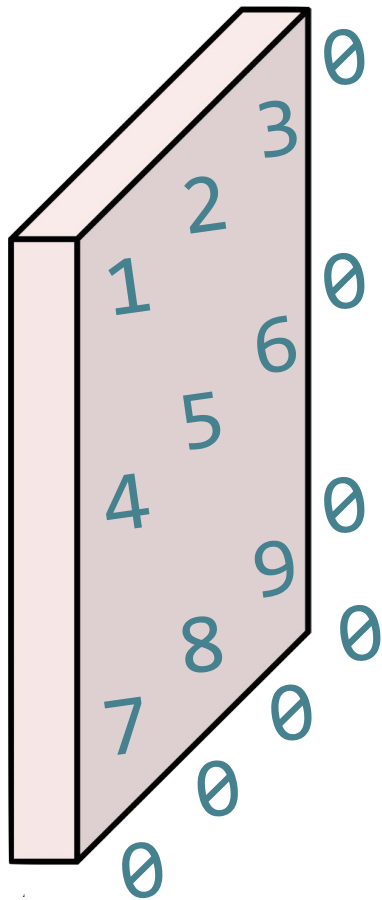
Simple convolution layer

Image: 1,3,3,1 image, Filter: 2,2,1,1, Stride: 1x1, No Padding

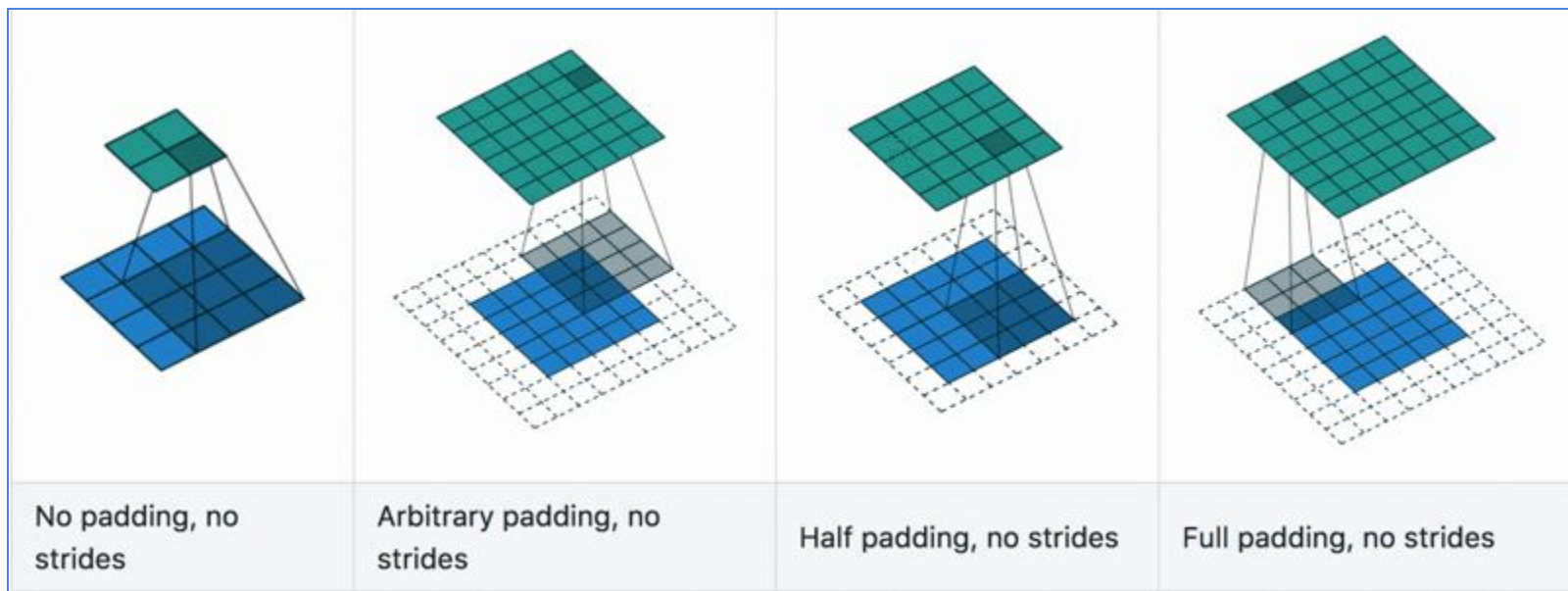


Simple convolution layer

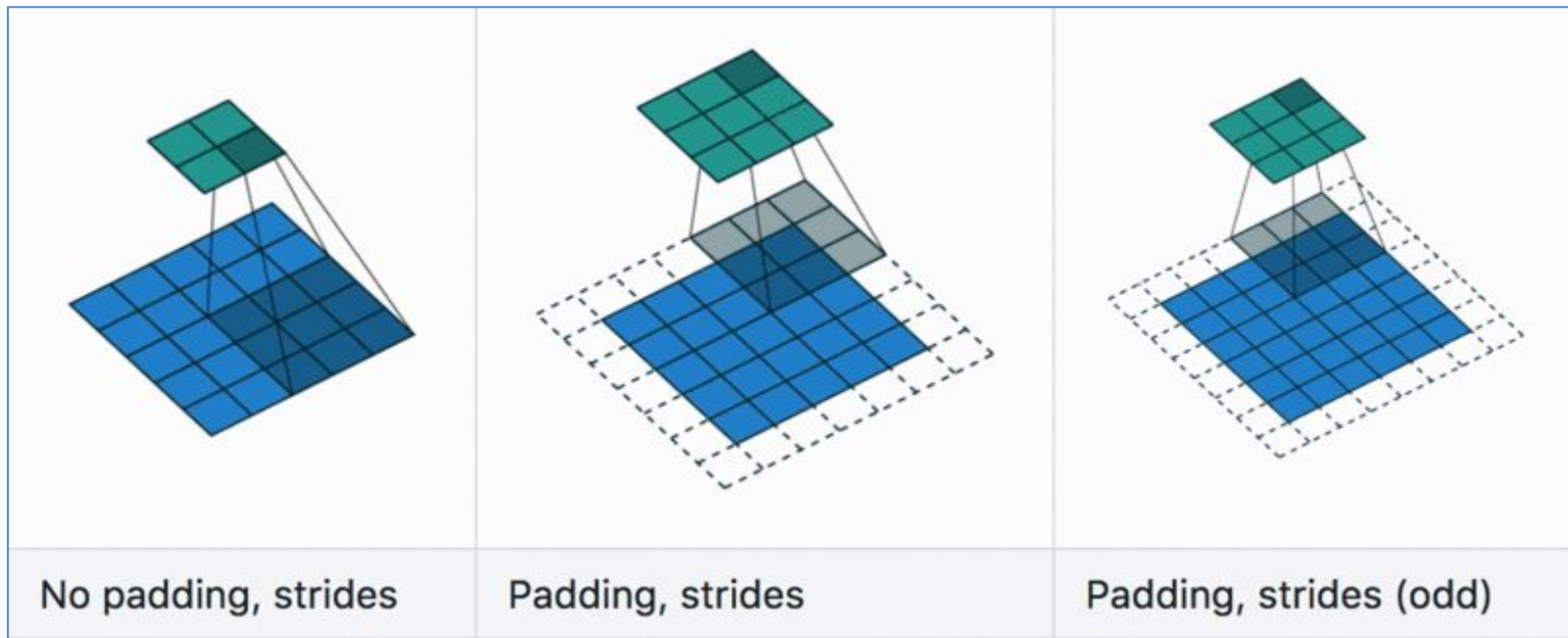
Image: 1,3,3,1 image, Filter: 2,2,1,1, Stride: 1x1, With padding



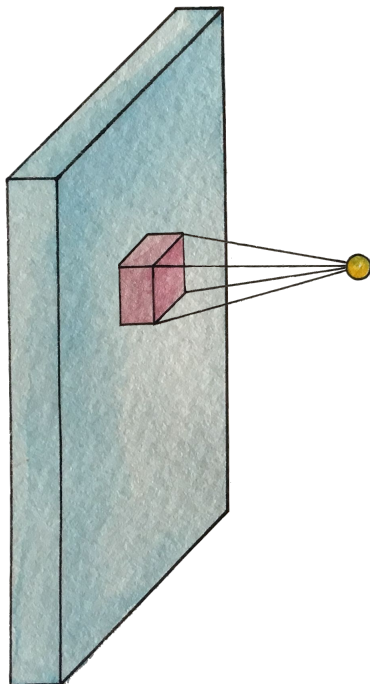
Convolution with padding in Action



Convolution with stride in Action



Max pooling



Single depth slice

| | | | |
|---|---|---|---|
| 1 | 1 | 2 | 4 |
| 5 | 6 | 7 | 8 |
| 3 | 2 | 1 | 0 |
| 1 | 2 | 3 | 4 |

max pool with 2x2 filters
and stride 2



| | |
|---|---|
| 6 | 8 |
| 3 | 4 |

Max Pooling in Action

| | | | | |
|---|---|---|---|---|
| 3 | 3 | 2 | 1 | 0 |
| 0 | 0 | 1 | 3 | 1 |
| 3 | 1 | 2 | 2 | 3 |
| 2 | 0 | 0 | 2 | 2 |
| 2 | 0 | 0 | 0 | 1 |

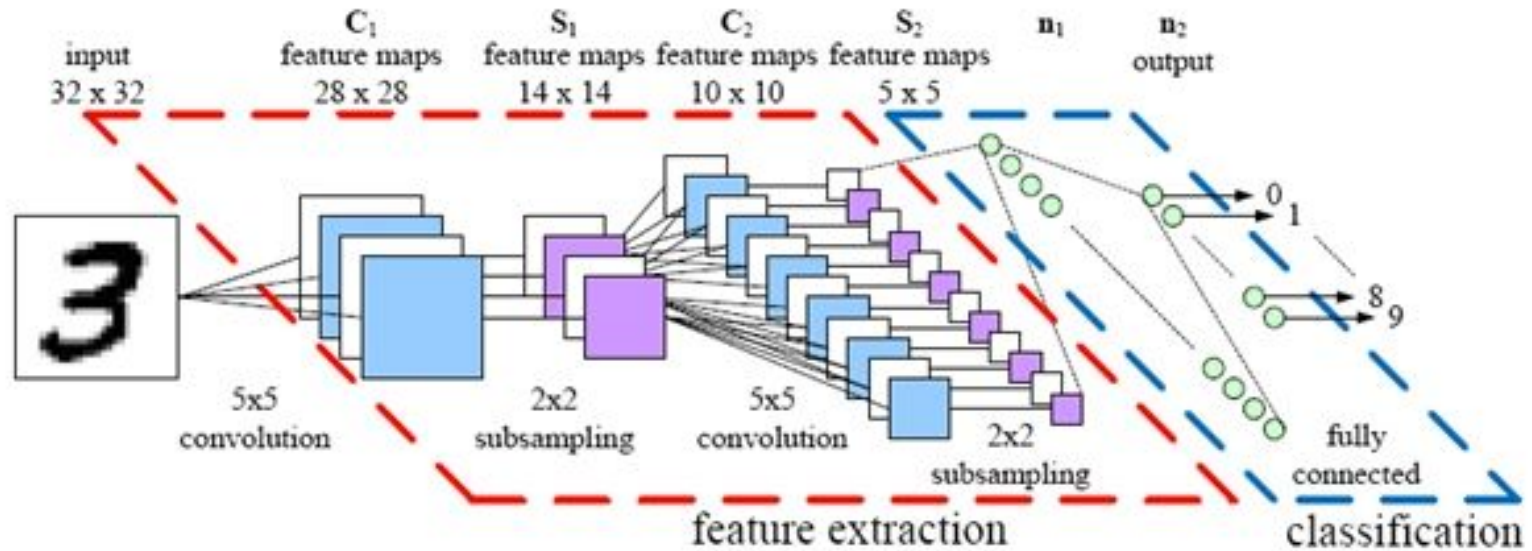
| | | |
|-----|-----|-----|
| 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 |
| 3.0 | 2.0 | 3.0 |

Avg Pooling in Action

| | | | | |
|---|---|---|---|---|
| 3 | 3 | 2 | 1 | 0 |
| 0 | 0 | 1 | 3 | 1 |
| 3 | 1 | 2 | 2 | 3 |
| 2 | 0 | 0 | 2 | 2 |
| 2 | 0 | 0 | 0 | 1 |

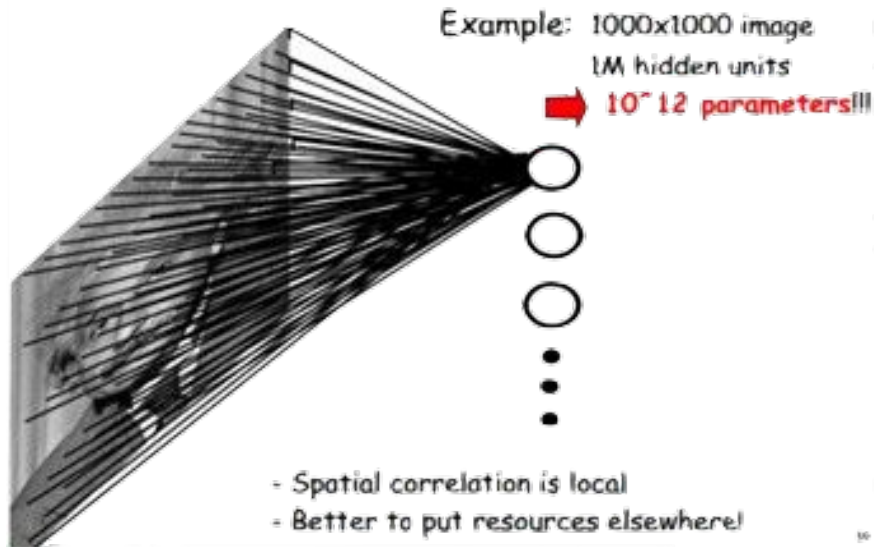
| | | |
|-----|-----|-----|
| 1.7 | 1.7 | 1.7 |
| 1.0 | 1.2 | 1.8 |
| 1.1 | 0.8 | 1.3 |

CNN

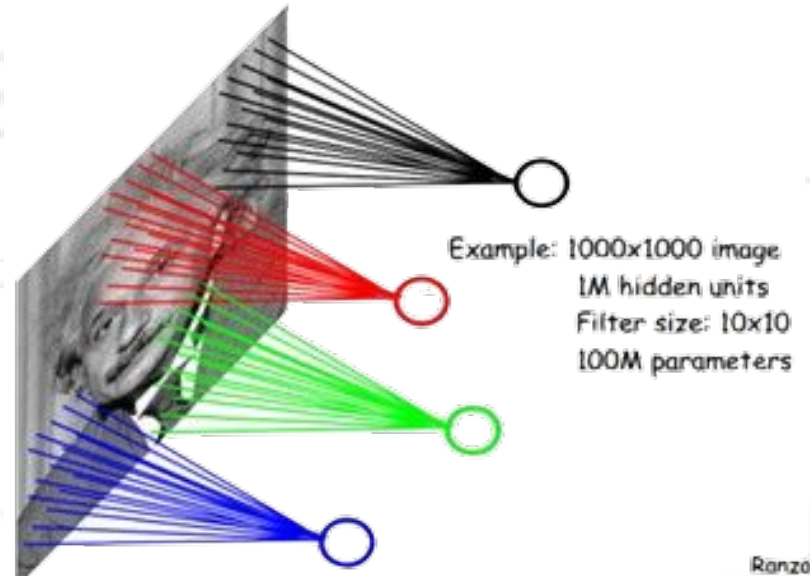


Locally Connected Features

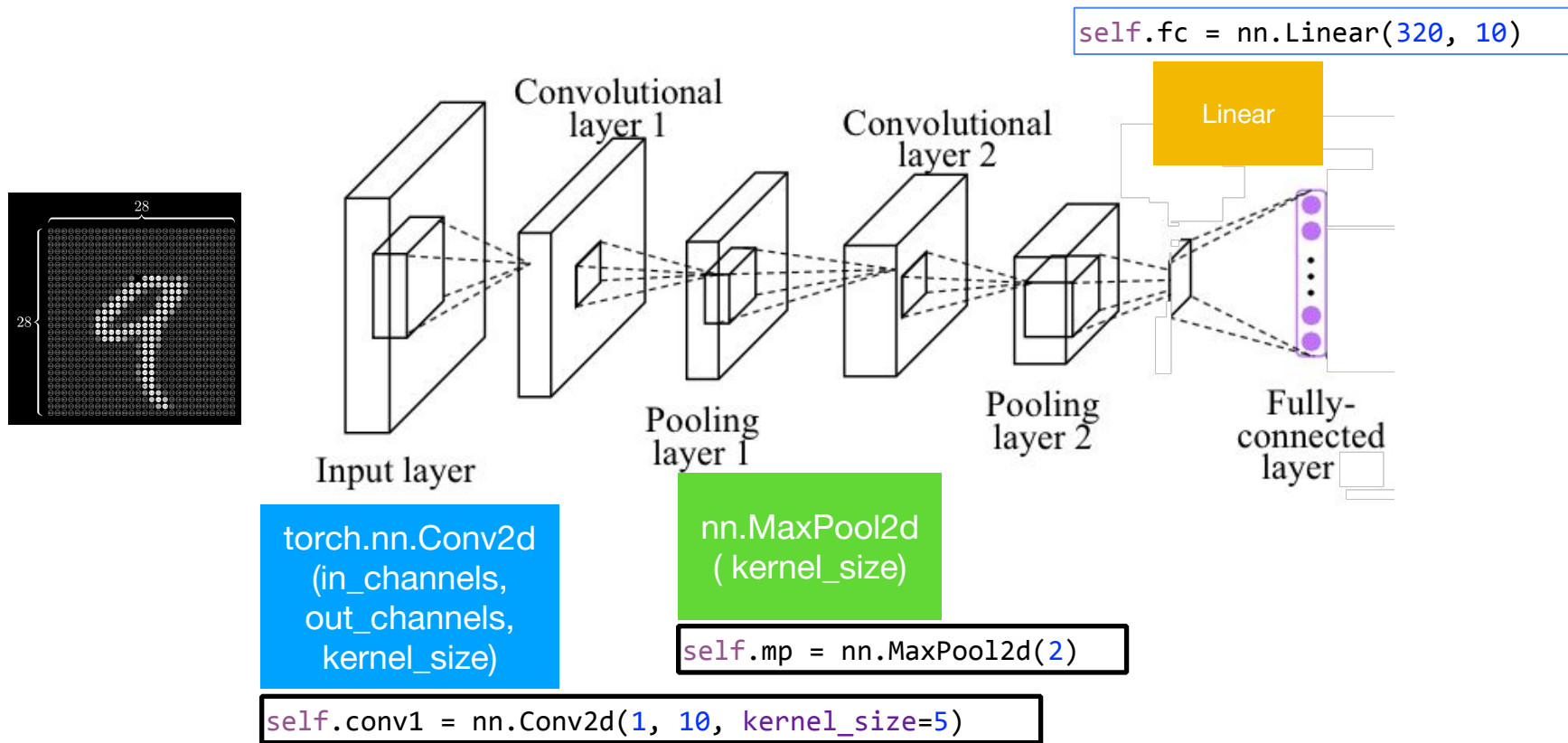
FULLY CONNECTED NEURAL NET

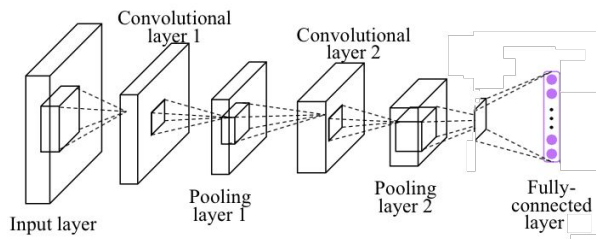


LOCALLY CONNECTED NEURAL NET



Simple CNN





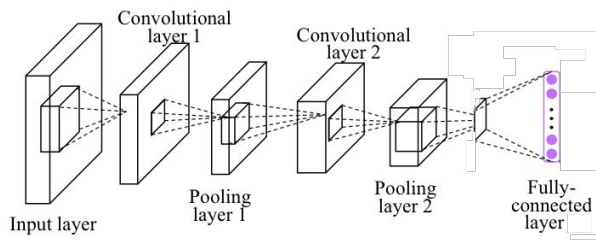
Simple CNN



```
class Net(nn.Module):
```

```
    def __init__(self):
        super(Net, self).__init__()
        self.conv1 = nn.Conv2d(1, 10, kernel_size=5)
        self.conv2 = nn.Conv2d(10, 20, kernel_size=5)
        self.mp = nn.MaxPool2d(2)
        self.fc = nn.Linear(100???, 10) # ??? -> 10
```

```
    def forward(self, x):
        in_size = x.size(0)
        x = F.relu(self.mp(self.conv1(x)))
        x = F.relu(self.mp(self.conv2(x)))
        x = x.view(in_size, -1) # flatten the tensor
        x = self.fc(x)
        return F.log_softmax(x)
```



Simple CNN

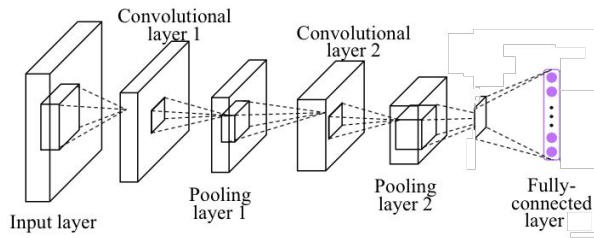


```
class Net(nn.Module):
```

```
    def __init__(self):
        super(Net, self).__init__()
        self.conv1 = nn.Conv2d(1, 10, kernel_size=5)
        self.conv2 = nn.Conv2d(10, 20, kernel_size=5)
        self.mp = nn.MaxPool2d(2)
        self.fc = nn.Linear(100???, 10) # ??? -> 10
```

```
    def forward(self, x):
        in_size = x.size(0)
        x = F.relu(self.mp(self.conv1(x)))
        x = F.relu(self.mp(self.conv2(x)))
        x = x.view(in_size, -1) # flatten the tensor
        x = self.fc(x)
        return F.log_softmax(x)
```

```
RuntimeError: size mismatch, m1: [64 x 320], m2: [100 x 10]
```



Simple CNN

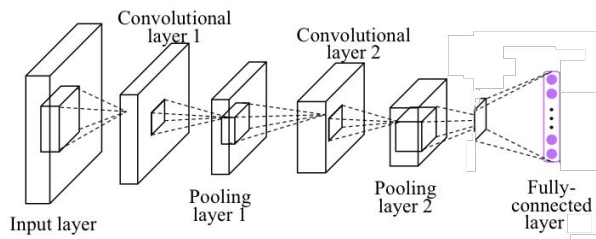


```
class Net(nn.Module):
```

```
def __init__(self):
    super(Net, self).__init__()
    self.conv1 = nn.Conv2d(1, 10, kernel_size=5)
    self.conv2 = nn.Conv2d(10, 20, kernel_size=5)
    self.mp = nn.MaxPool2d(2)
    self.fc = nn.Linear(320, 10) # 320 -> 10

def forward(self, x):
    in_size = x.size(0)
    x = F.relu(self.mp(self.conv1(x)))
    x = F.relu(self.mp(self.conv2(x)))
    x = x.view(in_size, -1) # flatten the tensor
    x = self.fc(x)
    return F.log_softmax(x)
```

```
RuntimeError: size mismatch, m1: [64 x 320], m2: [100 x 10]
```

Simple CNN



```
class Net(nn.Module):
```

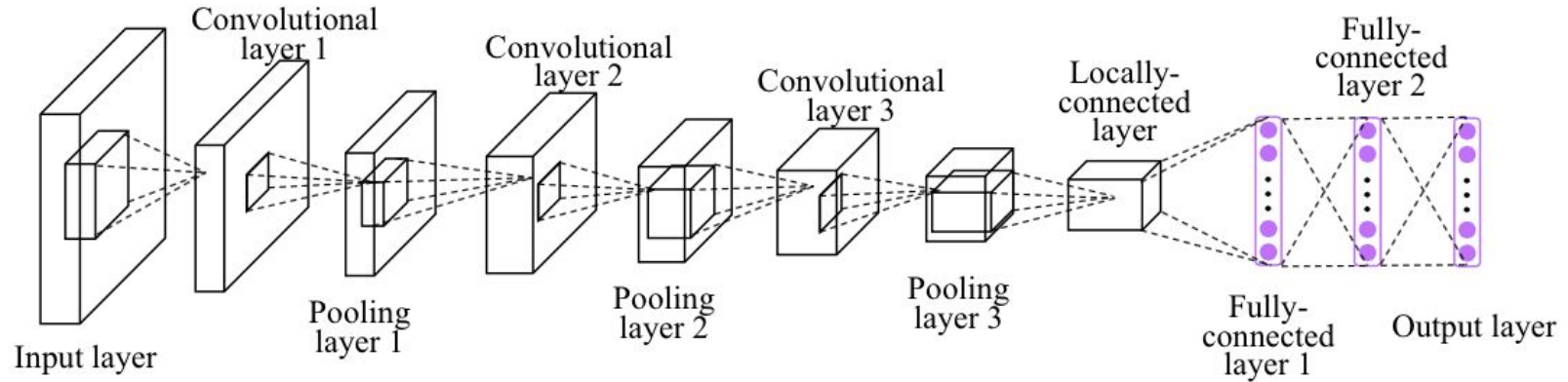
```
def __init__(self):
    super(Net, self).__init__()
    self.conv1 = nn.Conv2d(1, 10, kernel_size=5)
    self.conv2 = nn.Conv2d(10, 20, kernel_size=5)
    self.mp = nn.MaxPool2d(2)
    self.fc = nn.Linear(320, 10) # 320 -> 10

def forward(self, x):
    in_size = x.size(0)
    x = F.relu(self.mp(self.conv1(x)))
    x = F.relu(self.mp(self.conv2(x)))
    x = x.view(in_size, -1) # flatten the tensor
    x = self.fc(x)
    return F.log_softmax(x)
```

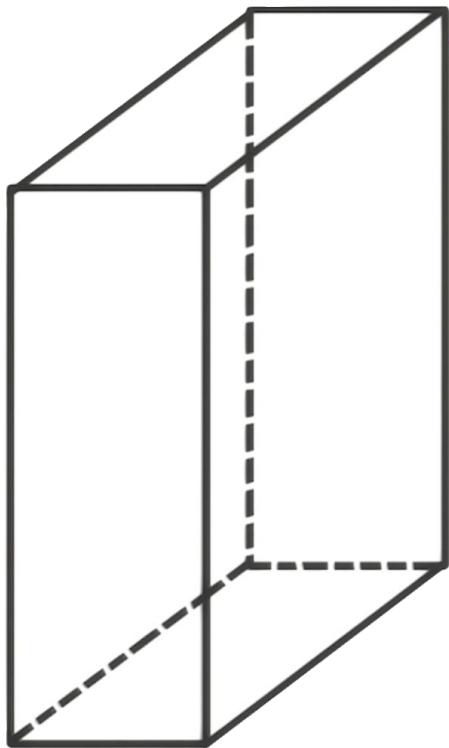
| | |
|------------------------------------|----------------|
| Train Epoch: 9 [46080/60000 (77%)] | Loss: 0.108415 |
| Train Epoch: 9 [46720/60000 (78%)] | Loss: 0.140700 |
| Train Epoch: 9 [47360/60000 (79%)] | Loss: 0.090830 |
| Train Epoch: 9 [48000/60000 (80%)] | Loss: 0.031640 |
| Train Epoch: 9 [48640/60000 (81%)] | Loss: 0.014934 |
| Train Epoch: 9 [49280/60000 (82%)] | Loss: 0.090210 |
| Train Epoch: 9 [49920/60000 (83%)] | Loss: 0.074975 |
| Train Epoch: 9 [50560/60000 (84%)] | Loss: 0.058671 |
| Train Epoch: 9 [51200/60000 (85%)] | Loss: 0.023464 |
| Train Epoch: 9 [51840/60000 (86%)] | Loss: 0.018025 |
| Train Epoch: 9 [52480/60000 (87%)] | Loss: 0.098865 |
| Train Epoch: 9 [53120/60000 (88%)] | Loss: 0.013985 |
| Train Epoch: 9 [53760/60000 (90%)] | Loss: 0.070476 |
| Train Epoch: 9 [54400/60000 (91%)] | Loss: 0.065411 |
| Train Epoch: 9 [55040/60000 (92%)] | Loss: 0.028783 |
| Train Epoch: 9 [55680/60000 (93%)] | Loss: 0.008333 |
| Train Epoch: 9 [56320/60000 (94%)] | Loss: 0.020412 |
| Train Epoch: 9 [56960/60000 (95%)] | Loss: 0.036749 |
| Train Epoch: 9 [57600/60000 (96%)] | Loss: 0.163087 |
| Train Epoch: 9 [58240/60000 (97%)] | Loss: 0.117539 |
| Train Epoch: 9 [58880/60000 (98%)] | Loss: 0.032256 |
| Train Epoch: 9 [59520/60000 (99%)] | Loss: 0.026360 |

Test set: Average loss: 0.0483, Accuracy: 9846/10000 (98%)

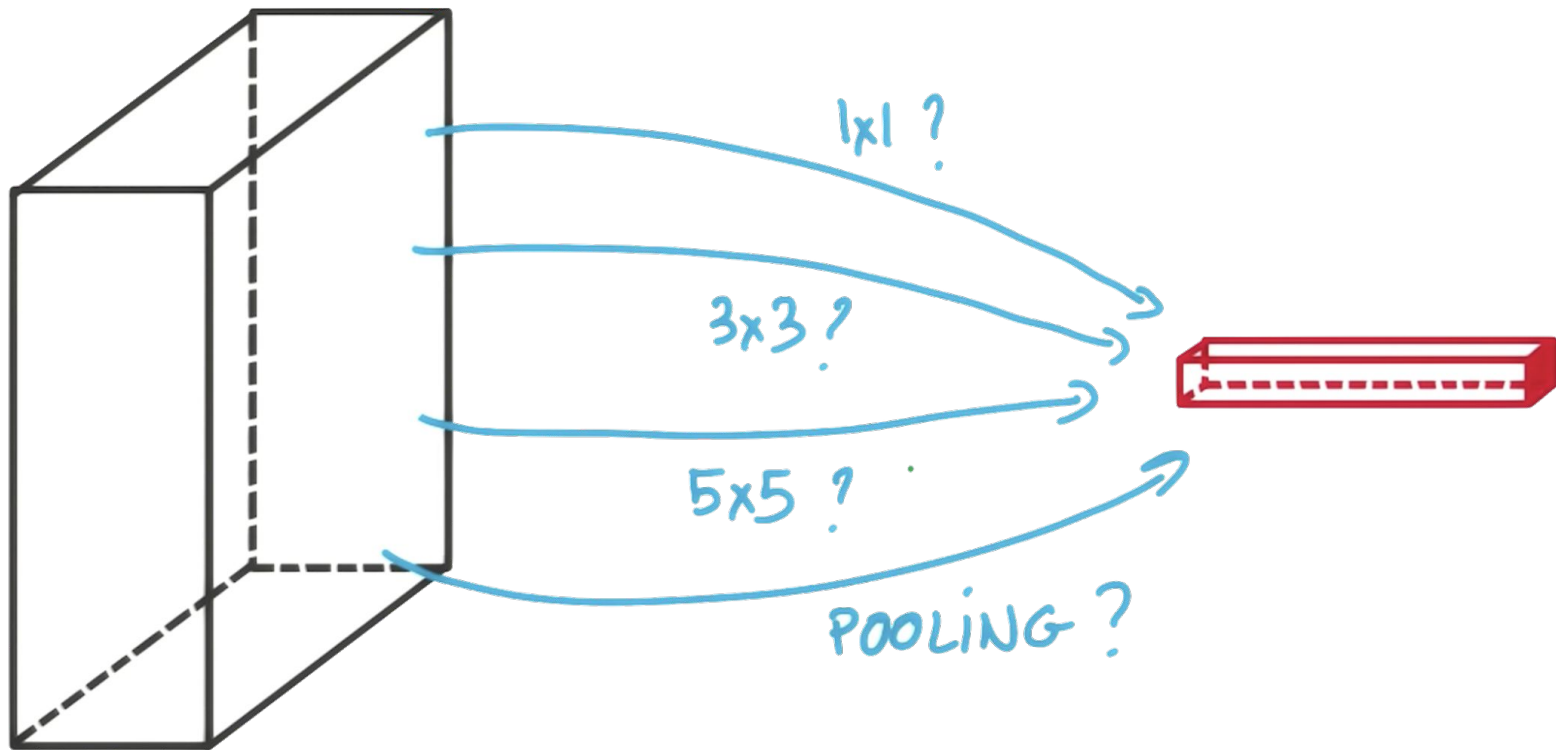
Exercise 10-1: Implement CNN more layers



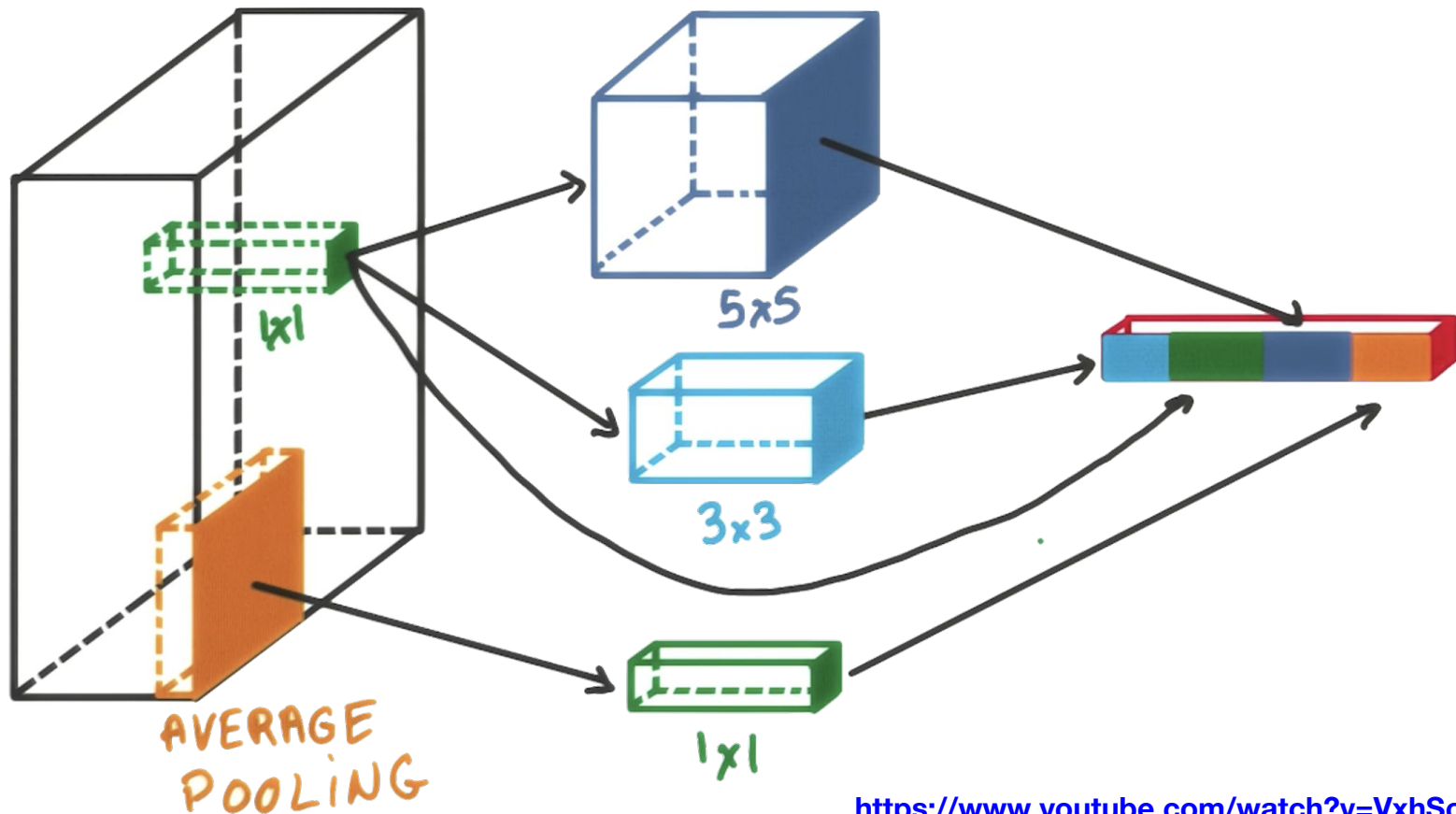
INCEPTION MODULES



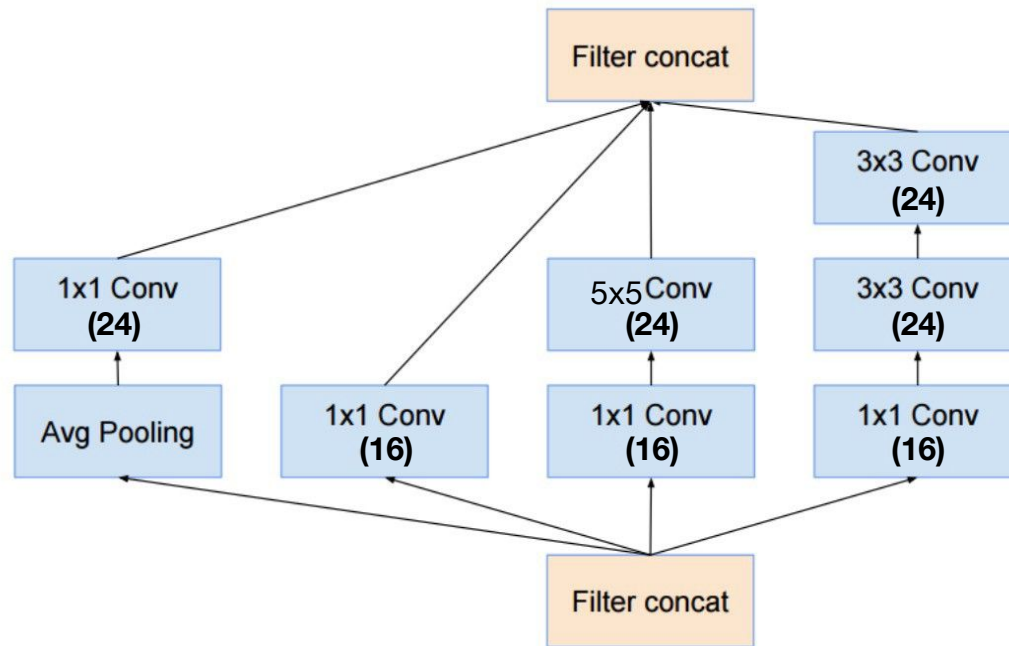
INCEPTION MODULES

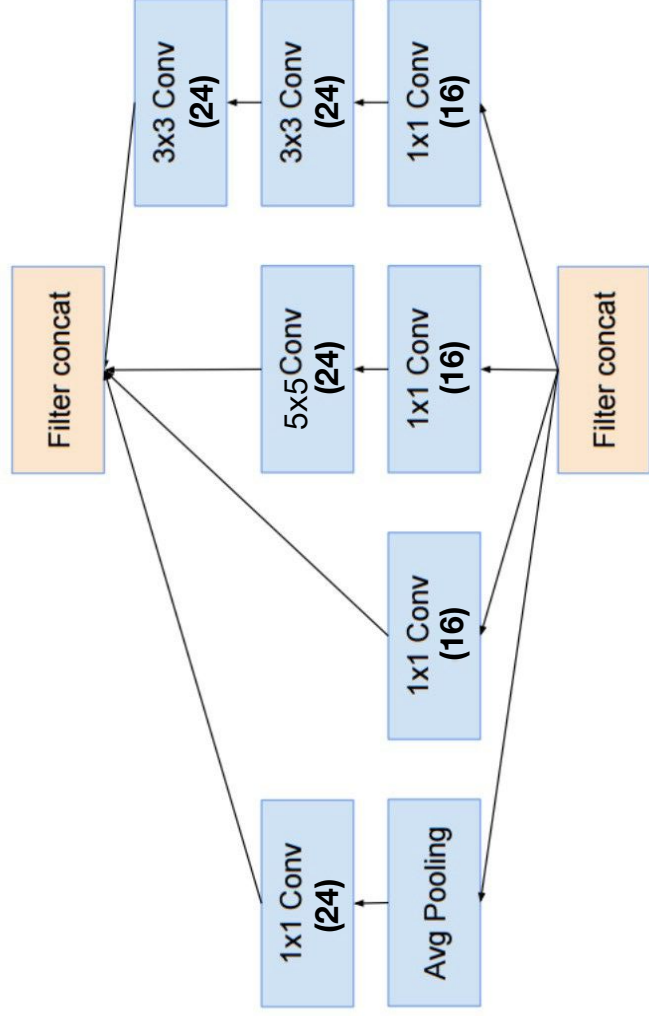


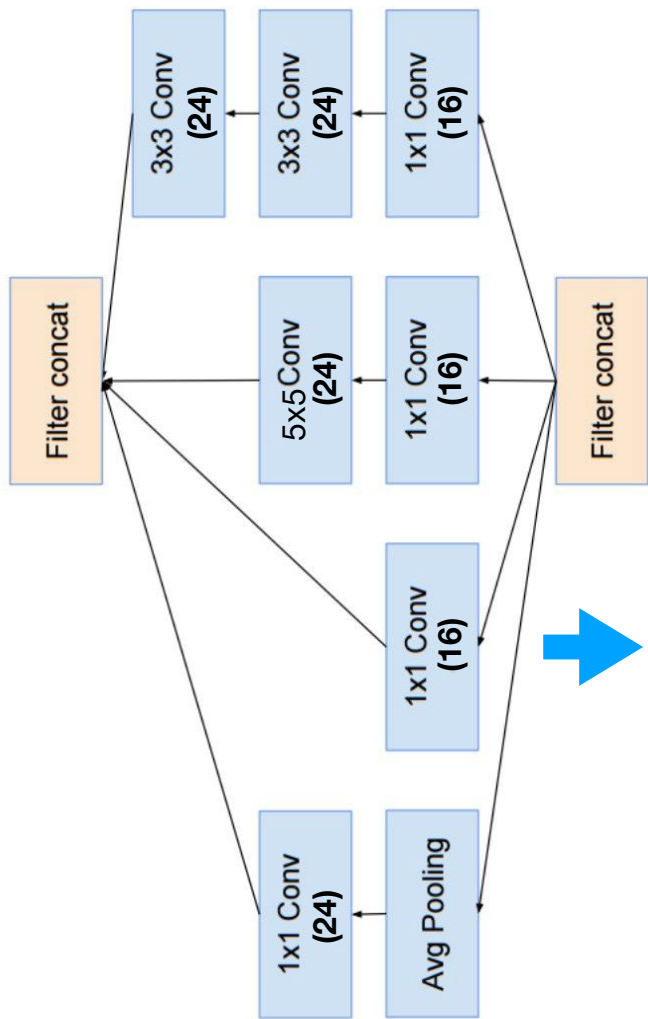
INCEPTION MODULES



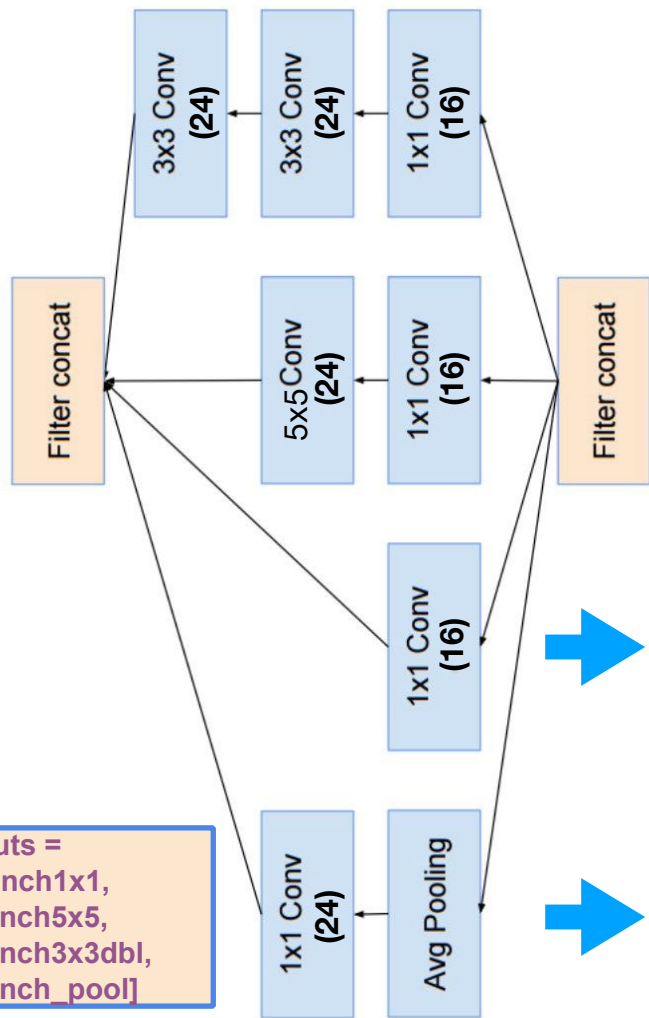
Inception Module







```
self.branch1x1 = nn.Conv2d(in_channels, 16, kernel_size=1)  
branch1x1 = self.branch1x1(x)
```



```

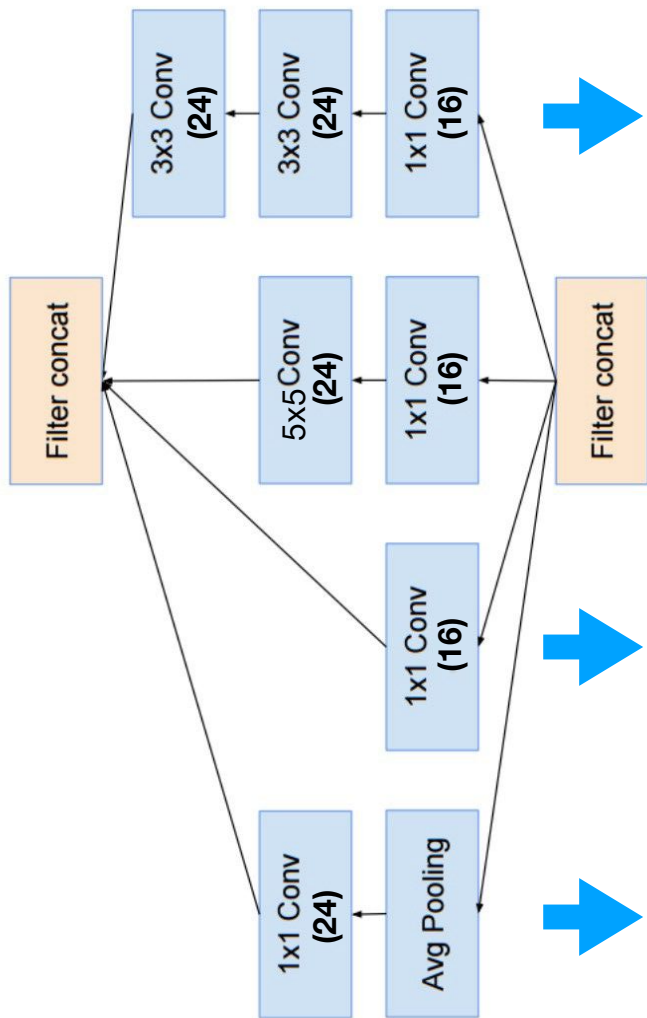
self.branch1x1 = nn.Conv2d(in_channels, 16, kernel_size=1)
branch1x1 = self.branch1x1(x)

```

```

self.branch_pool = nn.Conv2d(in_channels, 24, kernel_size=1)
branch_pool = F.avg_pool2d(x, kernel_size=3, stride=1, padding=1)
branch_pool = self.branch_pool(branch_pool)

```



```

self.branch3x3dbl_1 = nn.Conv2d(in_channels, 16, kernel_size=1)
self.branch3x3dbl_2 = nn.Conv2d(16, 24, kernel_size=3, padding=1)
self.branch3x3dbl_3 = nn.Conv2d(24, 24, kernel_size=3, padding=1)

```

```

branch3x3dbl = self.branch3x3dbl_1(x)
branch3x3dbl = self.branch3x3dbl_2(branch3x3dbl)
branch3x3dbl = self.branch3x3dbl_3(branch3x3dbl)

```

```

self.branch1x1 = nn.Conv2d(in_channels, 16, kernel_size=1)

```

```

branch1x1 = self.branch1x1(x)

```

```

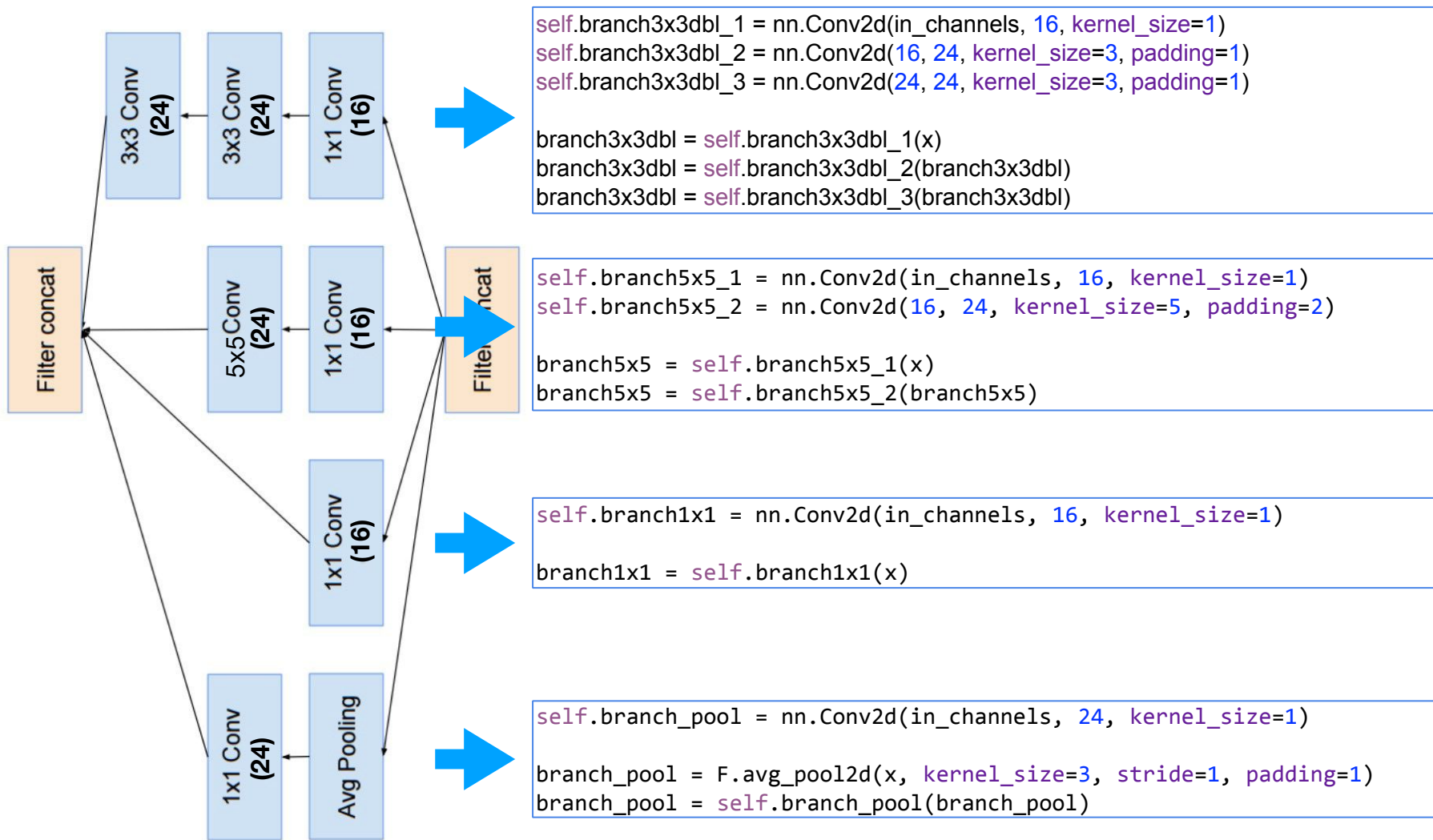
self.branch_pool = nn.Conv2d(in_channels, 24, kernel_size=1)

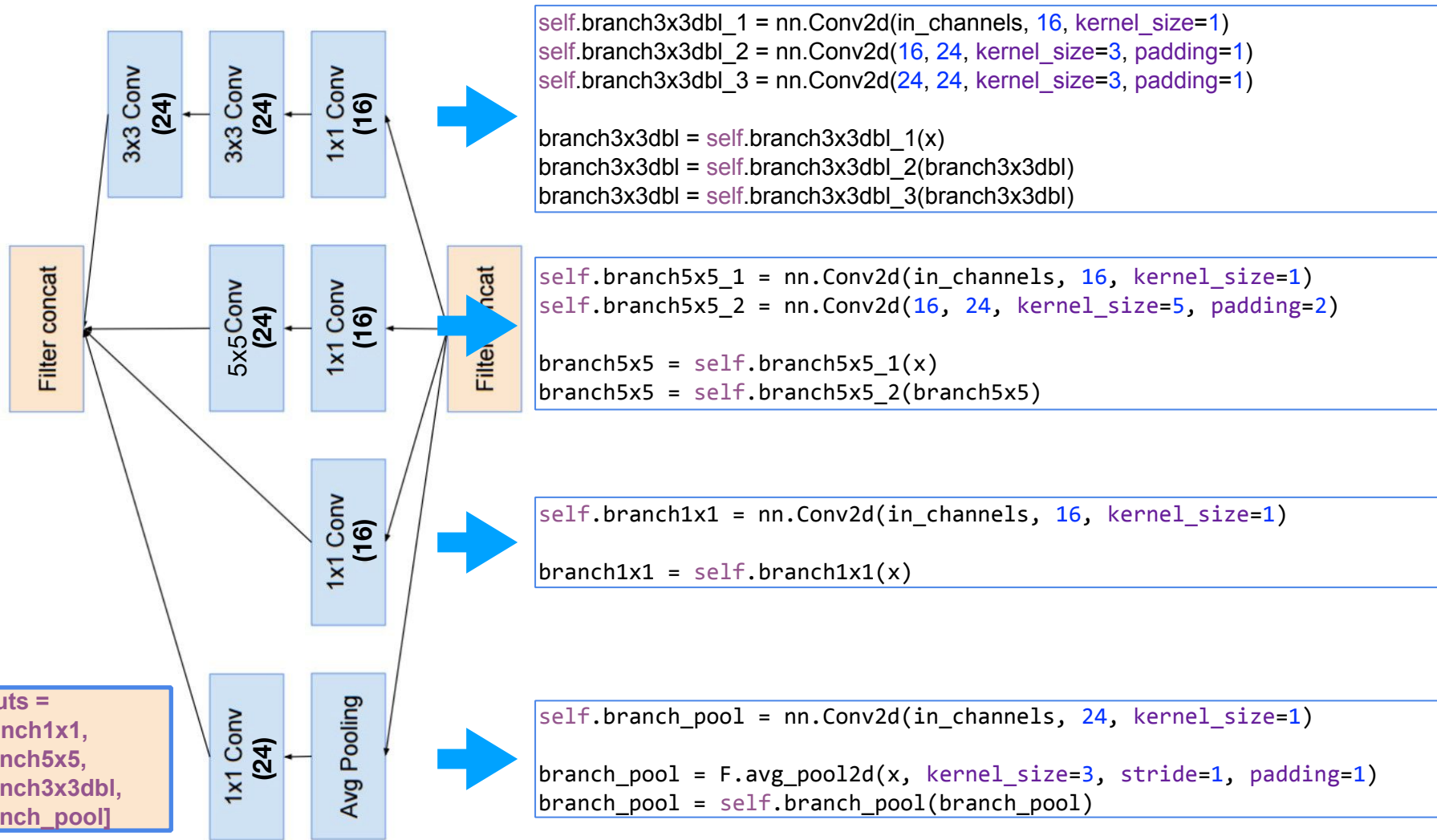
```

```

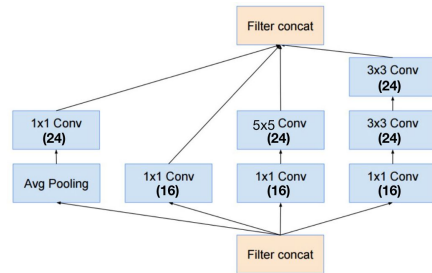
branch_pool = F.avg_pool2d(x, kernel_size=3, stride=1, padding=1)
branch_pool = self.branch_pool(branch_pool)

```





Inception Module



```
class InceptionA(nn.Module):
    def __init__(self, in_channels):
        super(InceptionA, self).__init__()
        self.branch1x1 = nn.Conv2d(in_channels, 16, kernel_size=1)

        self.branch5x5_1 = nn.Conv2d(in_channels, 16, kernel_size=1)
        self.branch5x5_2 = nn.Conv2d(16, 24, kernel_size=5, padding=2)

        self.branch3x3dbl_1 = nn.Conv2d(in_channels, 16, kernel_size=1)
        self.branch3x3dbl_2 = nn.Conv2d(16, 24, kernel_size=3, padding=1)
        self.branch3x3dbl_3 = nn.Conv2d(24, 24, kernel_size=3, padding=1)

        self.branch_pool = nn.Conv2d(in_channels, 24, kernel_size=1)

    def forward(self, x):
        branch1x1 = self.branch1x1(x)

        branch5x5 = self.branch5x5_1(x)
        branch5x5 = self.branch5x5_2(branch5x5)

        branch3x3dbl = self.branch3x3dbl_1(x)
        branch3x3dbl = self.branch3x3dbl_2(branch3x3dbl)
        branch3x3dbl = self.branch3x3dbl_3(branch3x3dbl)

        branch_pool = F.avg_pool2d(x, kernel_size=3, stride=1, padding=1)
        branch_pool = self.branch_pool(branch_pool)

        outputs = [branch1x1, branch5x5, branch3x3dbl, branch_pool]
        return torch.cat(outputs, 1)
```

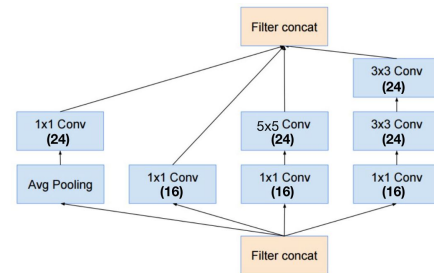
```
class Net(nn.Module):
    def __init__(self):
        super(Net, self).__init__()
        self.conv1 = nn.Conv2d(1, 10, kernel_size=5)
        self.conv2 = nn.Conv2d(88, 20, kernel_size=5)

        self.incept1 = InceptionA(in_channels=10)
        self.incept2 = InceptionA(in_channels=20)

        self.mp = nn.MaxPool2d(2)
        self.fc = nn.Linear(1408, 10)

    def forward(self, x):
        in_size = x.size(0)
        x = F.relu(self.mp(self.conv1(x)))
        x = self.incept1(x)
        x = F.relu(self.mp(self.conv2(x)))
        x = self.incept2(x)
        x = x.view(in_size, -1) # flatten the tensor
        x = self.fc(x)
        return F.log_softmax(x)
```

Inception Module



| | |
|------------------------------------|----------------|
| Train Epoch: 9 [44800/60000 (75%)] | Loss: 0.064180 |
| Train Epoch: 9 [45440/60000 (76%)] | Loss: 0.020339 |
| Train Epoch: 9 [46080/60000 (77%)] | Loss: 0.061476 |
| Train Epoch: 9 [46720/60000 (78%)] | Loss: 0.039662 |
| Train Epoch: 9 [47360/60000 (79%)] | Loss: 0.026798 |
| Train Epoch: 9 [48000/60000 (80%)] | Loss: 0.071569 |
| Train Epoch: 9 [48640/60000 (81%)] | Loss: 0.003835 |
| Train Epoch: 9 [49280/60000 (82%)] | Loss: 0.005564 |
| Train Epoch: 9 [49920/60000 (83%)] | Loss: 0.020116 |
| Train Epoch: 9 [50560/60000 (84%)] | Loss: 0.128114 |
| Train Epoch: 9 [51200/60000 (85%)] | Loss: 0.016599 |
| Train Epoch: 9 [51840/60000 (86%)] | Loss: 0.006995 |
| Train Epoch: 9 [52480/60000 (87%)] | Loss: 0.111267 |
| Train Epoch: 9 [53120/60000 (88%)] | Loss: 0.052126 |
| Train Epoch: 9 [53760/60000 (90%)] | Loss: 0.034962 |
| Train Epoch: 9 [54400/60000 (91%)] | Loss: 0.029465 |
| Train Epoch: 9 [55040/60000 (92%)] | Loss: 0.031482 |
| Train Epoch: 9 [55680/60000 (93%)] | Loss: 0.015132 |
| Train Epoch: 9 [56320/60000 (94%)] | Loss: 0.010435 |
| Train Epoch: 9 [56960/60000 (95%)] | Loss: 0.014344 |
| Train Epoch: 9 [57600/60000 (96%)] | Loss: 0.014952 |
| Train Epoch: 9 [58240/60000 (97%)] | Loss: 0.153132 |
| Train Epoch: 9 [58880/60000 (98%)] | Loss: 0.112024 |
| Train Epoch: 9 [59520/60000 (99%)] | Loss: 0.009406 |

Test set: Average loss: 0.0470, Accuracy: 9866/10000 **(99%)**

```
class Net(nn.Module):
```

```
    def __init__(self):
```

```
        super(Net, self).__init__()
```

```
        self.conv1 = nn.Conv2d(1, 10, kernel_size=5)
```

```
        self.conv2 = nn.Conv2d(88, 20, kernel_size=5)
```

```
        self.incept1 = InceptionA(in_channels=10)
```

```
        self.incept2 = InceptionA(in_channels=20)
```

```
        self.mp = nn.MaxPool2d(2)
```

```
        self.fc = nn.Linear(1408, 10)
```

```
    def forward(self, x):
```

```
        in_size = x.size(0)
```

```
        x = F.relu(self.mp(self.conv1(x)))
```

```
        x = self.incept1(x)
```

```
        x = F.relu(self.mp(self.conv2(x)))
```

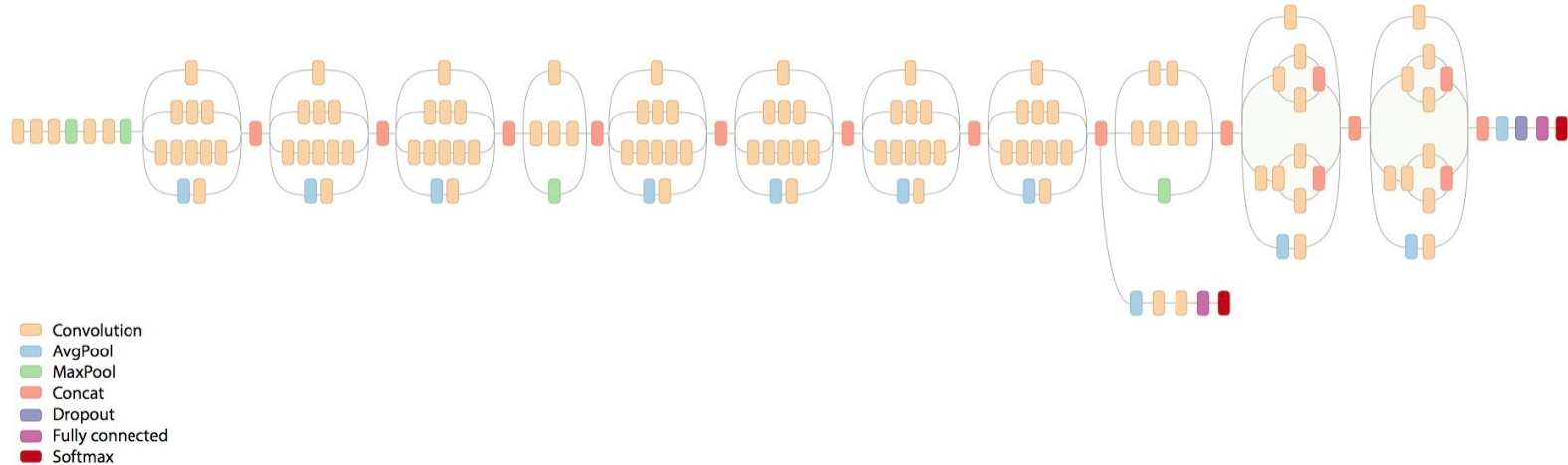
```
        x = self.incept2(x)
```

```
        x = x.view(in_size, -1) # flatten the tensor
```

```
        x = self.fc(x)
```

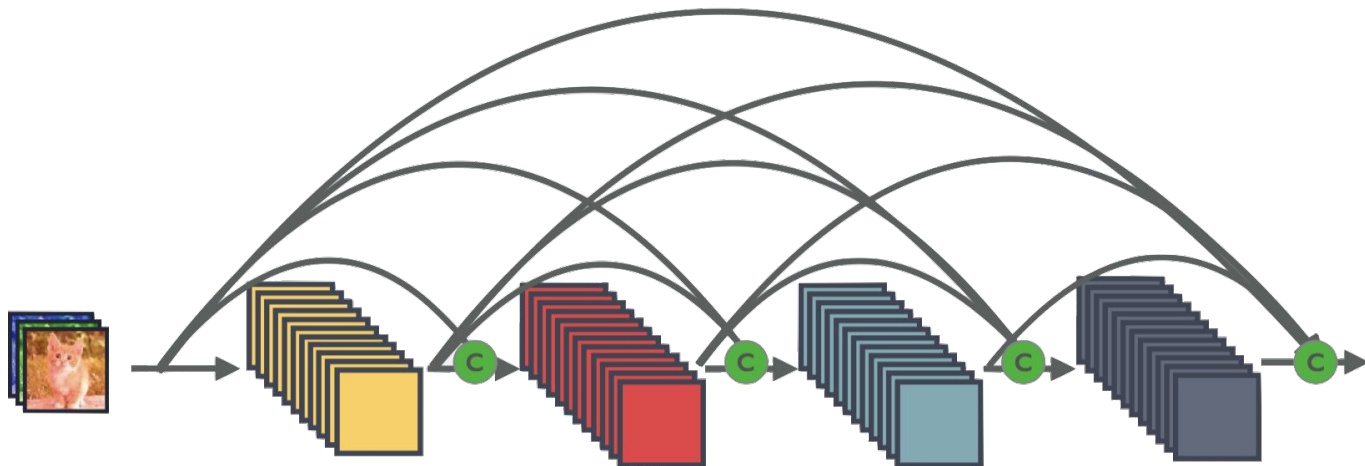
```
        return F.log_softmax(x)
```


Exercise 10-2: Implement full inception v3/v4



<https://research.googleblog.com/2016/08/improving-inception-and-image.html>

Exercise 10-3: Implement DenseNet



**WHAT
NEXT?**



Lecture 11: RNN