

Inception V1 / GoogLeNet

Inception V1 / GoogLeNet

- Proposed in 2014

Going deeper with convolutions

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Abstract

We propose a deep convolutional neural network architecture codenamed Inception, which was responsible for setting the new state of the art for classification and detection in the ImageNet Large-Scale Visual Recognition Challenge 2014 (ILSVRC14). The main hallmark of this architecture is the improved utilization of the computing resources inside the network. This was achieved by a carefully crafted design that allows for increasing the depth and width of the network while keeping the computational budget constant. To optimize quality, the architectural decisions were based on the Hebbian principle and the intuition of multi-scale processing. One particular incarnation used in our submission for ILSVRC14 is called GoogLeNet, a 22 layers deep network, the quality of which is assessed in the context of classification and detection.

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 - 2 initial convolution layers with max pooling
 - 9 inception modules
 - 2 fully connected layers
- Trained on imagenet dataset

Architecture: GoogLeNet

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| convolution | 7×7/2 | 112×112×64 | 1 | | | | | | | 2.7K | 34M |
| max pool | 3×3/2 | 56×56×64 | 0 | | | | | | | | |
| convolution | 3×3/1 | 56×56×192 | 2 | | 64 | 192 | | | | 112K | 360M |
| max pool | 3×3/2 | 28×28×192 | 0 | | | | | | | | |
| inception (3a) | | 28×28×256 | 2 | 64 | 96 | 128 | 16 | 32 | 32 | 159K | 128M |
| inception (3b) | | 28×28×480 | 2 | 128 | 128 | 192 | 32 | 96 | 64 | 380K | 304M |
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| inception (4a) | | 14×14×512 | 2 | 192 | 96 | 208 | 16 | 48 | 64 | 364K | 73M |
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| inception (4e) | | 14×14×832 | 2 | 256 | 160 | 320 | 32 | 128 | 128 | 840K | 170M |
| max pool | 3×3/2 | 7×7×832 | 0 | | | | | | | | |
| inception (5a) | | 7×7×832 | 2 | 256 | 160 | 320 | 32 | 128 | 128 | 1072K | 54M |
| inception (5b) | | 7×7×1024 | 2 | 384 | 192 | 384 | 48 | 128 | 128 | 1388K | 71M |
| avg pool | 7×7/1 | 1×1×1024 | 0 | | | | | | | | |
| dropout (40%) | | 1×1×1024 | 0 | | | | | | | | |
| linear | | 1×1×1000 | 1 | | | | | | | 1000K | 1M |
| softmax | | 1×1×1000 | 0 | | | | | | | | |

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Input
56 X 56 X 64

 Analytics
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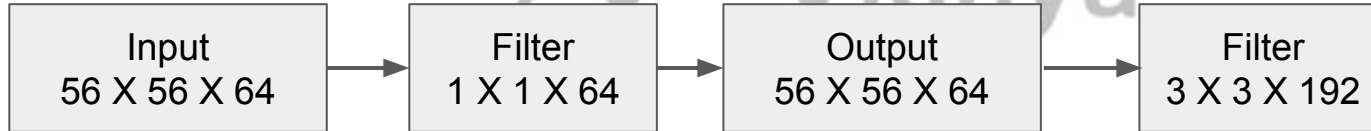
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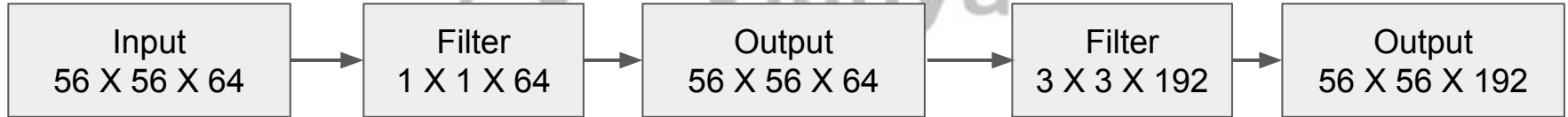
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28 X 28 X 192

Architecture: GoogLeNet

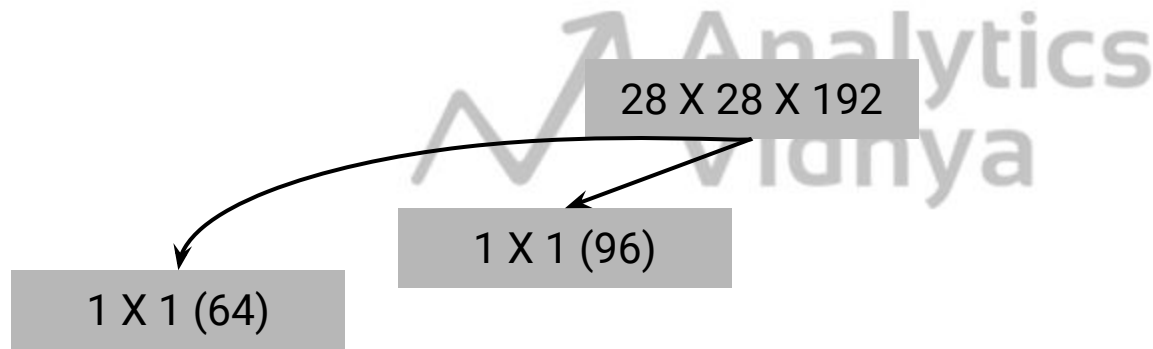
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28 X 28 X 192

1 X 1 (64)

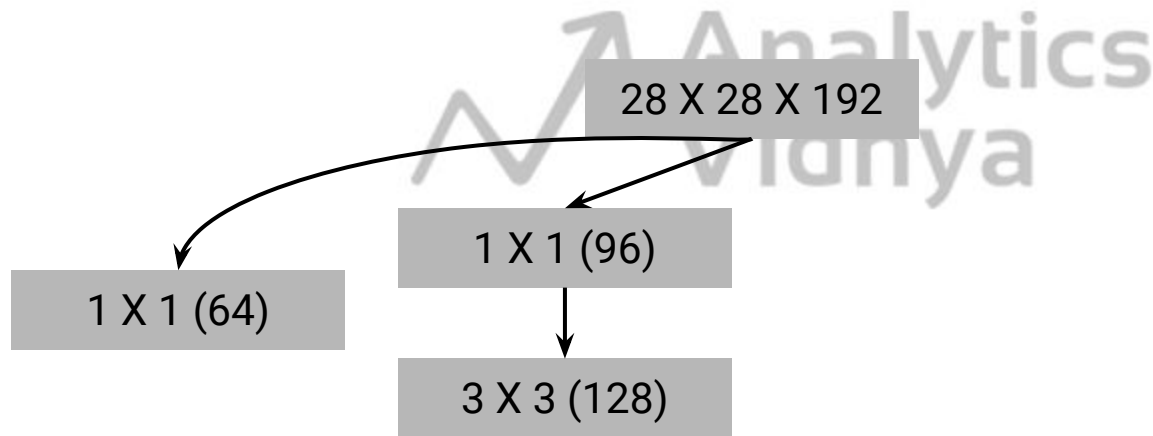
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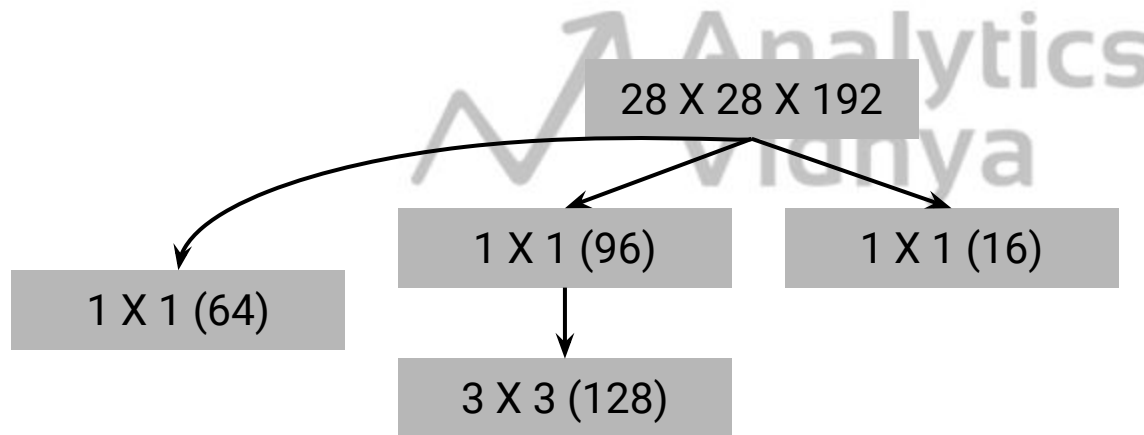
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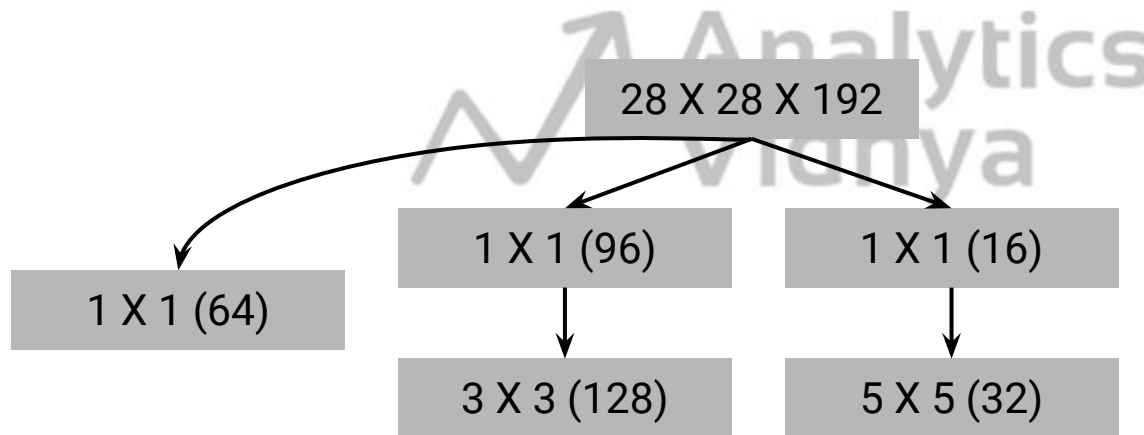
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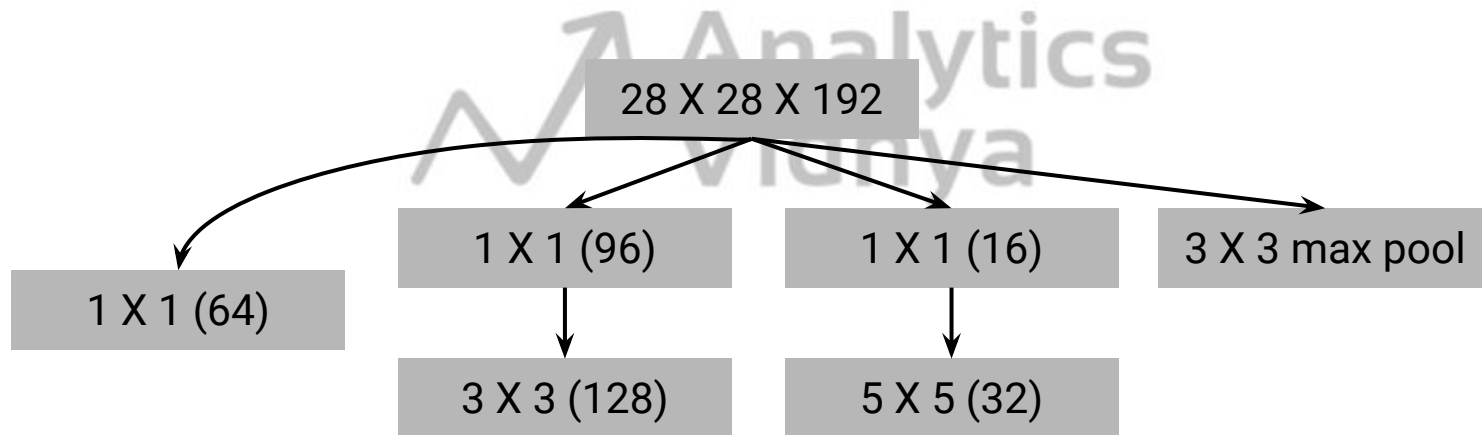
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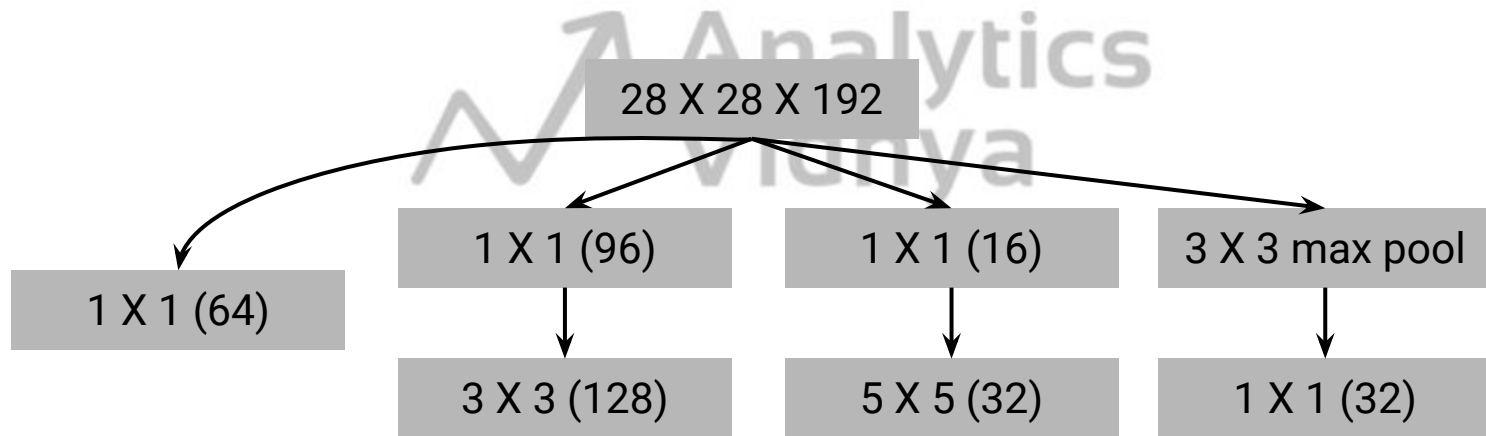
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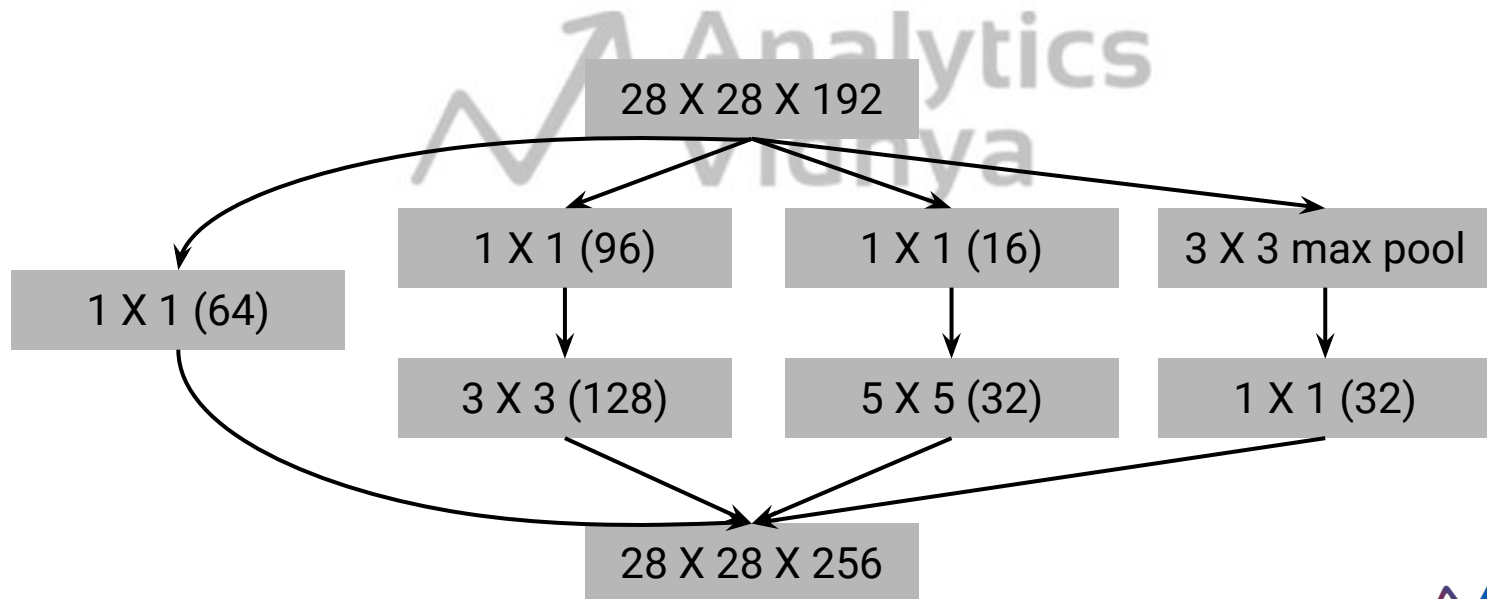
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| inception (5a) | | 7×7×832 | 2 | 256 | 160 | 320 | 32 | 128 | 128 | 1072K | 54M |
| inception (5b) | | 7×7×1024 | 2 | 384 | 192 | 384 | 48 | 128 | 128 | 1388K | 71M |

Architecture: GoogLeNet

| type | patch size/ stride | output size | depth | #1×1 | #3×3 reduce | #3×3 | #5×5 reduce | #5×5 | pool proj | params | ops |
|----------------|-----------------------|----------------|-------|------|----------------|------|----------------|------|--------------|--------|------|
| convolution | 7×7/2 | 112×112×64 | 1 | | | | | | | 2.7K | 34M |
| max pool | 3×3/2 | 56×56×64 | 0 | | | | | | | | |
| convolution | 3×3/1 | 56×56×192 | 2 | | 64 | 192 | | | | 112K | 360M |
| max pool | 3×3/2 | 28×28×192 | 0 | | | | | | | | |
| inception (3a) | | 28×28×256 | 2 | 64 | 96 | 128 | 16 | 32 | 32 | 159K | 128M |
| inception (3b) | | 28×28×480 | 2 | 128 | 128 | 192 | 32 | 96 | 64 | 380K | 304M |
| max pool | 3×3/2 | 14×14×480 | 0 | | | | | | | | |
| inception (4a) | | 14×14×512 | 2 | 192 | 96 | 208 | 16 | 48 | 64 | 364K | 73M |
| inception (4b) | | 14×14×512 | 2 | 160 | 112 | 224 | 24 | 64 | 64 | 437K | 88M |
| inception (4c) | | 14×14×512 | 2 | 128 | 128 | 256 | 24 | 64 | 64 | 463K | 100M |
| inception (4d) | | 14×14×528 | 2 | 112 | 144 | 288 | 32 | 64 | 64 | 580K | 119M |
| inception (4e) | | 14×14×832 | 2 | 256 | 160 | 320 | 32 | 128 | 128 | 840K | 170M |
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| avg pool | 7×7/1 | 1×1×1024 | 0 | | | | | | | | |

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| inception (5b) | | 7×7×1024 | 2 | 384 | 192 | 384 | 48 | 128 | 128 | 1388K | 71M |
| avg pool | 7×7/1 | 1×1×1024 | 0 | | | | | | | | |
| dropout (40%) | | 1×1×1024 | 0 | | | | | | | | |
| linear | | 1×1×1000 | 1 | | | | | | | 1000K | 1M |
| softmax | | 1×1×1000 | 0 | | | | | | | | |

Architecture: GoogLeNet

| type | patch size/ stride | output size | depth | #1×1 | #3×3 reduce | #3×3 | #5×5 reduce | #5×5 | pool proj | params | ops |
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| avg pool | 7×7/1 | 1×1×1024 | 0 | | | | | | | | |
| dropout (40%) | | 1×1×1024 | 0 | | | | | | | | |
| linear | | 1×1×1000 | 1 | | | | | | | 1000K | 1M |
| softmax | | 1×1×1000 | 0 | | | | | | | | |

Number of Parameters = 6.8 million

Auxiliary Classifiers

| type | patch size/ stride | output size | depth | #1×1 | #3×3 reduce | #3×3 | #5×5 reduce | #5×5 | pool proj | params | ops |
|----------------|-----------------------|----------------|-------|------|----------------|------|----------------|------|--------------|--------|------|
| convolution | 7×7/2 | 112×112×64 | 1 | | | | | | | 2.7K | 34M |
| max pool | 3×3/2 | 56×56×64 | 0 | | | | | | | | |
| convolution | 3×3/1 | 56×56×192 | 2 | | 64 | 192 | | | | 112K | 360M |
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| inception (5a) | | 7×7×832 | 2 | 256 | 160 | 320 | 32 | 128 | 128 | 1072K | 54M |
| inception (5b) | | 7×7×1024 | 2 | 384 | 192 | 384 | 48 | 128 | 128 | 1388K | 71M |
| avg pool | 7×7/1 | 1×1×1024 | 0 | | | | | | | | |
| dropout (40%) | | 1×1×1024 | 0 | | | | | | | | |
| linear | | 1×1×1000 | 1 | | | | | | | 1000K | 1M |
| softmax | | 1×1×1000 | 0 | | | | | | | | |

Auxiliary Classifiers

- Average pooling: filter size - 5 X 5, stride - 3



Auxiliary Classifiers

- Average pooling: filter size - 5 X 5, stride - 3
- 1 X 1 convolution with 128 filters: dimensionality reduction + ReLU



Auxiliary Classifiers

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- Fully connected layer with 1024 neurons + ReLU



Auxiliary Classifiers

- Average pooling: filter size - 5 X 5, stride - 3
- 1 X 1 convolution with 128 filters: dimensionality reduction + ReLU
- Fully connected layer with 1024 neurons + ReLU
- Dropout layer: dropout ratio - 70%

Auxiliary Classifiers

- Average pooling: filter size - 5 X 5, stride - 3
- 1 X 1 convolution with 128 filters: dimensionality reduction + ReLU
- Fully connected layer with 1024 neurons + ReLU
- Dropout layer: dropout ratio - 70%
- Fully connected layer with 1000 neurons + Softmax

Auxiliary Classifiers

- Average pooling: filter size - 5 X 5, stride - 3
- 1 X 1 convolution with 128 filters: dimensionality reduction + ReLU
- Fully connected layer with 1024 neurons + ReLU
- Dropout layer: dropout ratio - 70%
- Fully connected layer with 1000 neurons + Softmax
- No auxiliary classifier at inference time

Auxiliary Classifiers

$$\text{Total loss} = \text{Real_loss} + 0.3 * \text{aux_loss_1} + 0.3 * \text{aux_loss_2}$$

Summary: GoogLeNet



Summary: GoogLeNet

- It has 22 layers with learnable parameters



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- It has 22 layers with learnable parameters
- Takes RGB image as input



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- It has 22 layers with learnable parameters
- Takes RGB image as input
- Architecture details:
 - 2 initial convolution layers with max pooling
 - 9 inception modules
 - 2 fully connected layers
 - 2 Auxiliary classifiers

Summary: GoogLeNet

- It has 22 layers with learnable parameters
- Takes RGB image as input
- Architecture details:
 - 2 initial convolution layers with max pooling
 - 9 inception modules
 - 2 fully connected layers
 - 2 Auxiliary classifiers
- Total number of parameters: 6.8 million



Thank You