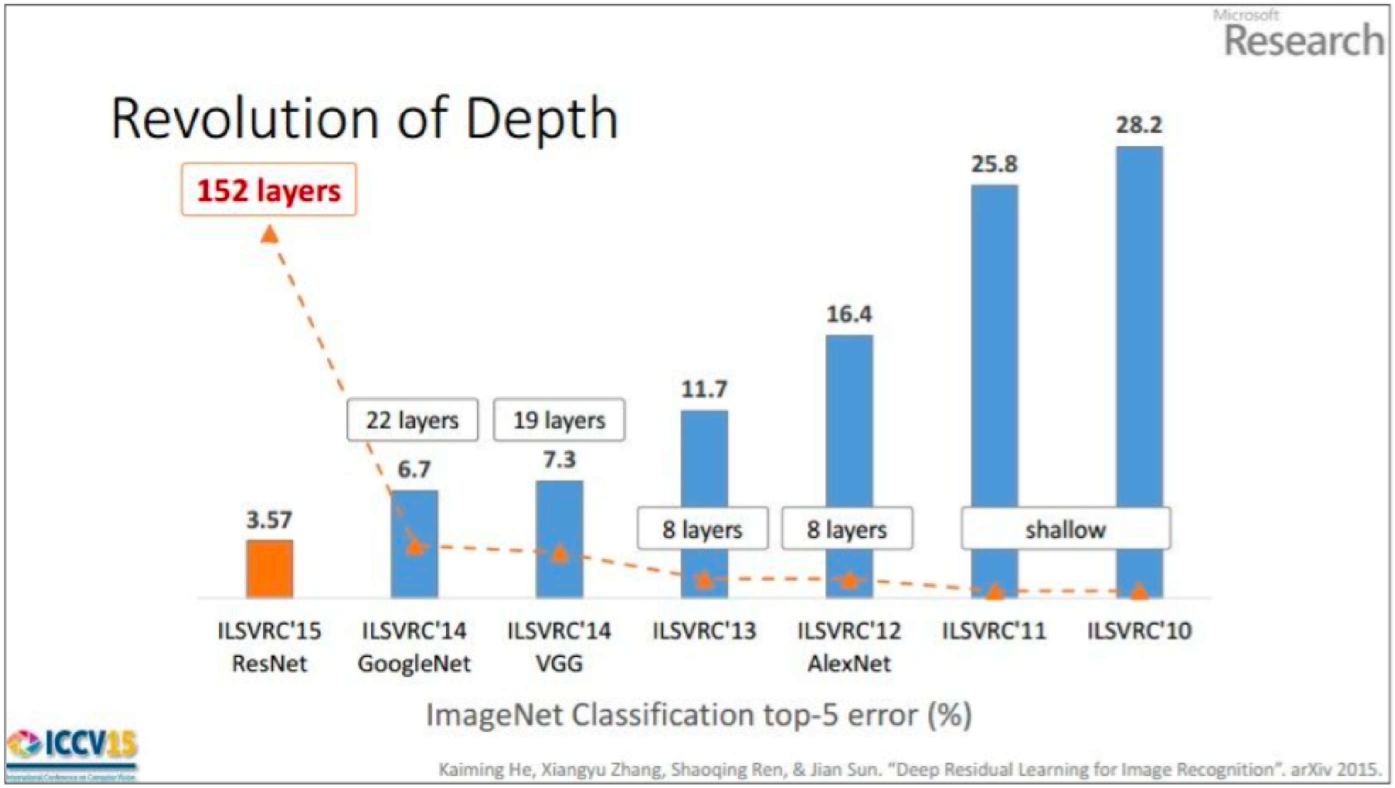
TTIC 31230, Fundamentals of Deep Learning

David McAllester, Winter 2018

Convolutional Neural Networks — CNNs

CNNs

Imagenet Classification. 1000 kinds of objects.

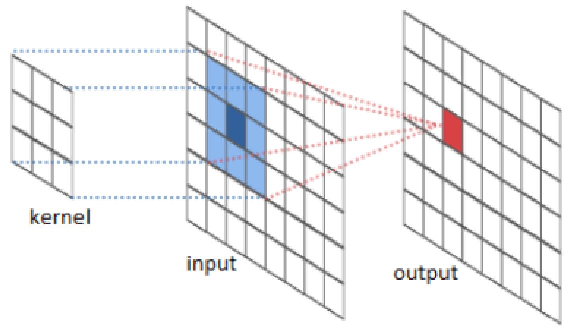


(slide from Kaiming He's recent presentation)

2016 error rate is 3.0%   2017 error rate is 2.25%

A CNN

A convolution slides a filter (a kernel) across an image.



$$W \qquad\qquad x \qquad\qquad y$$

River Trail Documentation

$$y[b,i,j,c_y] \;=\; W[\Delta i, \Delta j, c_x, c_y] x[b, i+\Delta i, j+\Delta j, c_x]$$

$$y[b,i,j,c_y] \text{ += } B[c_y]$$

Use Swap Rule to get Backward Method

$$y[b,i,j,c_y] \;=\; W[\Delta i,\Delta j,c_x,c_y]x[b,i+\Delta i,j+\Delta j,c_x]$$

$$W.\mathrm{grad}[\Delta i,\Delta j,c_x,c_y] \mathrel{+}= y.\mathrm{grad}[b,i,j,c_y]x[b,i+\Delta i,j+\Delta_j,c_x]$$

$$x.\mathrm{grad}[b,i{+}\Delta i,j{+}\Delta j,c_x] \mathrel{+}= W[\Delta i,\Delta j,c_x,c_y]y.\mathrm{grad}[b,i,j,c_y]$$

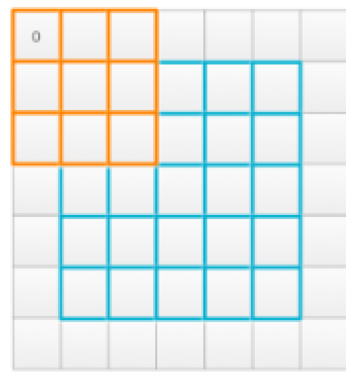
A Convolution Class in EDF

In EDF we would define a class for convolution parameter packages.

We would then construct the computation node for the output using Python code.

```
Y = Relu(Conv(Phi,X)).
```

Padding



Jonathan Hui

If we pad the input with zeros then the input and output can have the same spatial dimensions.

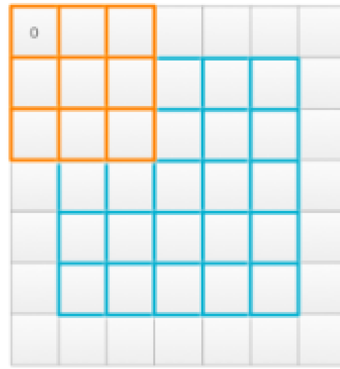
Zero Padding in NumPy

In NumPy we can add a zero padding of width p to an image as follows:

```
padded = np.zeros(W + 2*p,  H + 2*p)

padded[p:W+p, p:H+p] = x
```

Padding



Jonathan Hui

Let x' (full square) be the padding of x (blue square). y also has the blue shape.

$$y[b,i,j,c_y] = W[\Delta i, \Delta j, c_x, c_y]x'[b, i+\Delta i, j+\Delta j, c_x] + B[c_y]$$

For padding p and a filter of width $2p+1$, we get that y has the same spatial dimensions as x.

Strides

We can move the filter by a “stride” s for each spatial step.

$$y[b,i,j,c_y] = W[\Delta i, \Delta j, c_x, c_y]x[b, s*i+\Delta i, s*j+\Delta j, c_x] + B[c_y]$$

Max Pooling

$$y[b,i,j,c] = \max_{\Delta i, \Delta j} \; x[b, s*i+\Delta i, \; s*j+\Delta j, \; c]$$

This is typically done with a stride greater than one so that the image dimension is reduced.

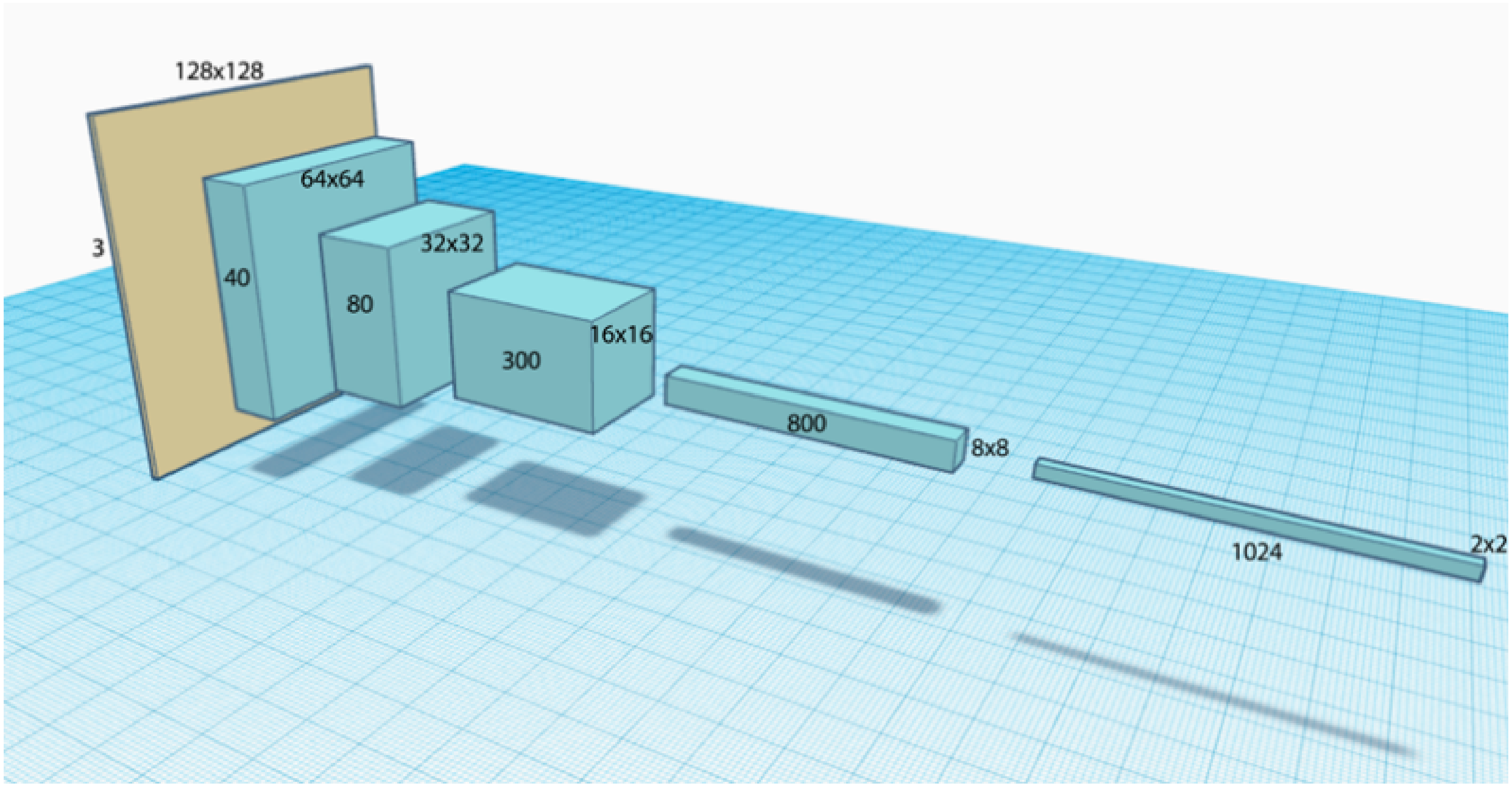
Fully Connected (FC) Layers

We reshape $x[b, x, y, c]$ to $x[b, (x, y, c)]$ and convert to using an MLP.

Basics

- Padding
- Convolution
- Stides
- Max Pooling
- Fully Connected Layers

A Sequence of "Images"



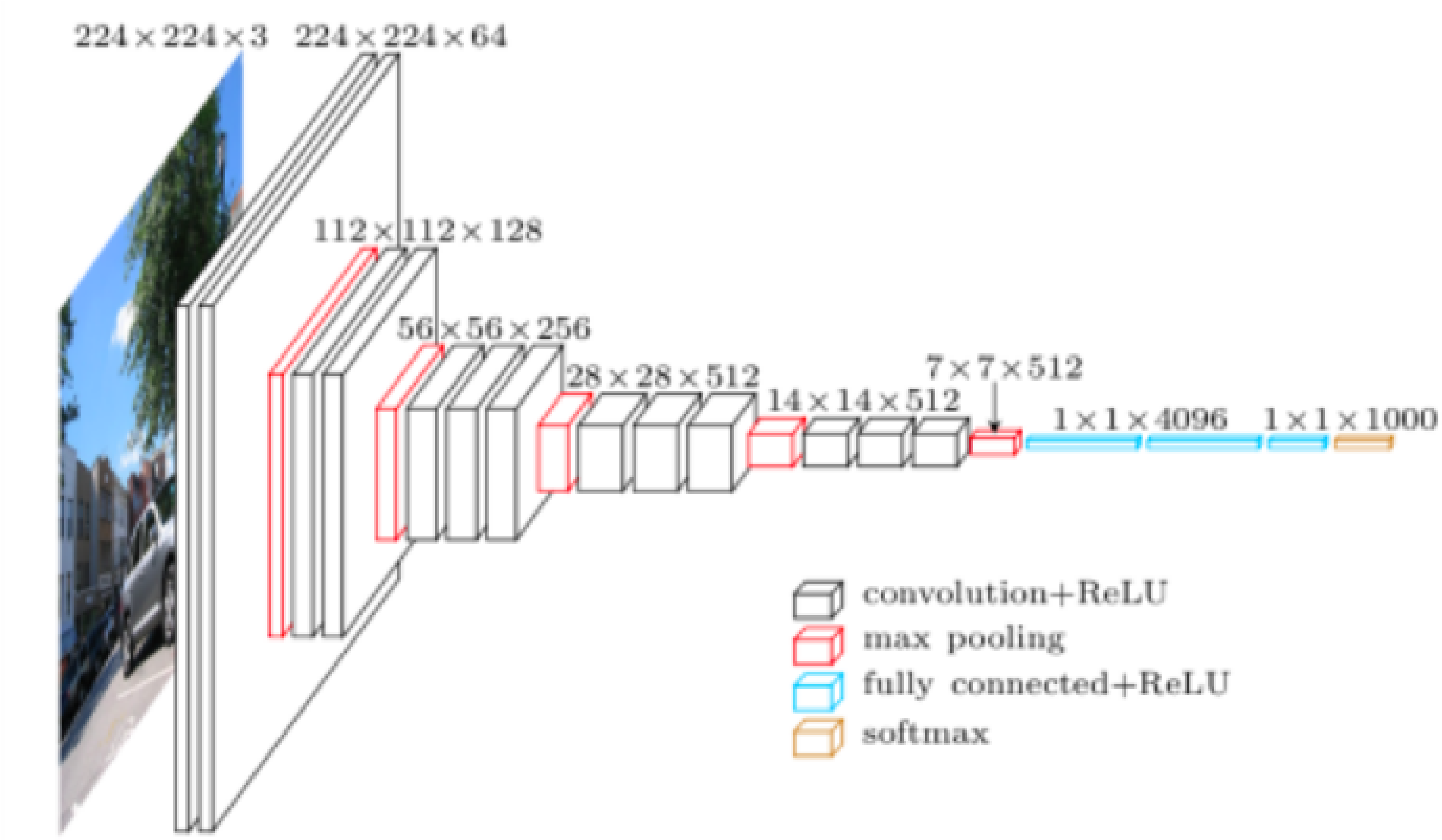
Jonathan Hui

Alexnet

Full (simplified) AlexNet architecture:
[227x227x3] INPUT
[55x55x96] CONV1: 96 11x11 filters at stride 4, pad 0
[27x27x96] MAX POOL1: 3x3 filters at stride 2
[27x27x96] NORM1: Normalization layer
[27x27x256] CONV2: 256 5x5 filters at stride 1, pad 2
[13x13x256] MAX POOL2: 3x3 filters at stride 2
[13x13x256] NORM2: Normalization layer
[13x13x384] CONV3: 384 3x3 filters at stride 1, pad 1
[13x13x384] CONV4: 384 3x3 filters at stride 1, pad 1
[13x13x256] CONV5: 256 3x3 filters at stride 1, pad 1
[6x6x256] MAX POOL3: 3x3 filters at stride 2
[4096] FC6: 4096 neurons
[4096] FC7: 4096 neurons
[1000] FC8: 1000 neurons (class scores)

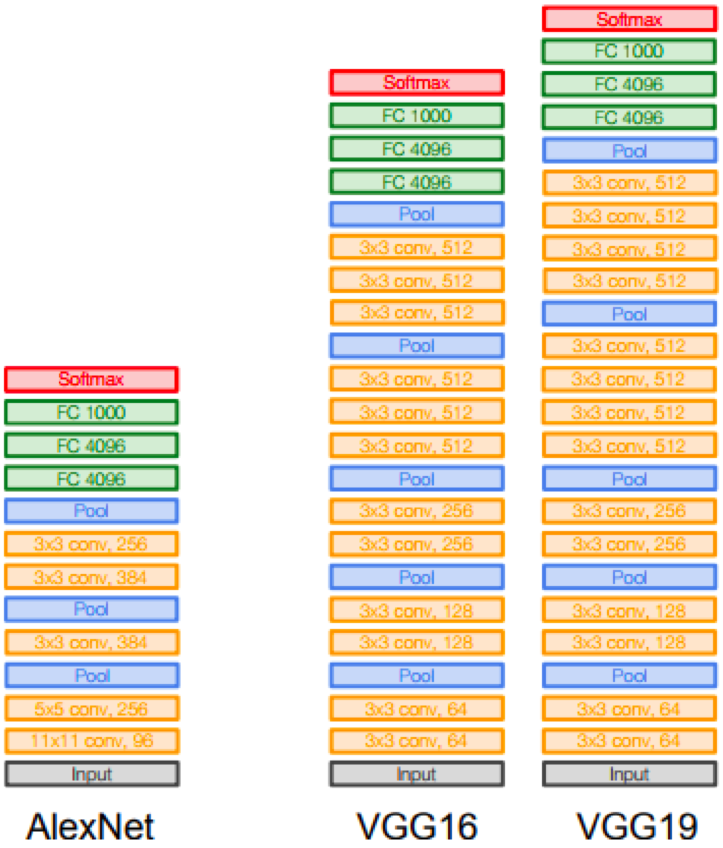
Stanford CS231

VGG, Zisserman, 2014



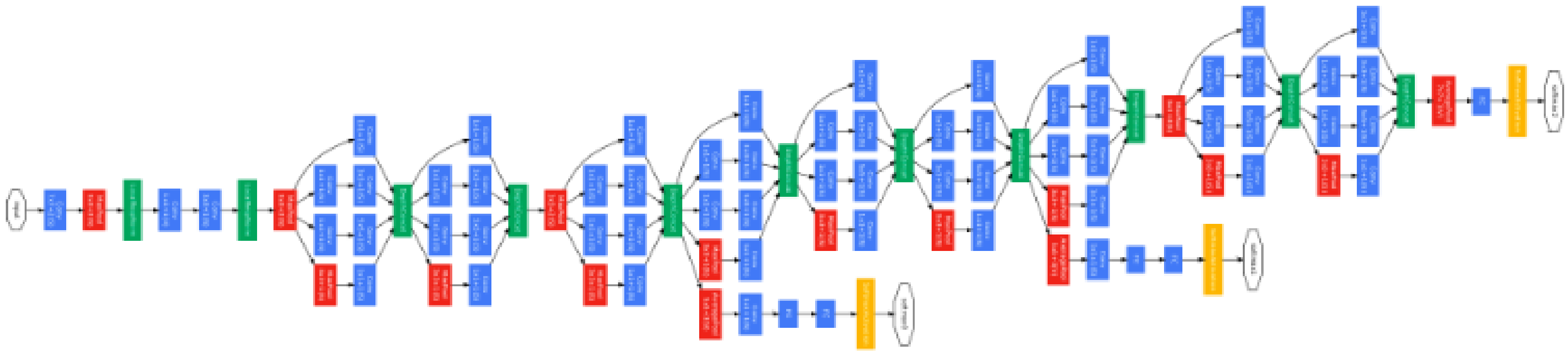
Davi Frossard

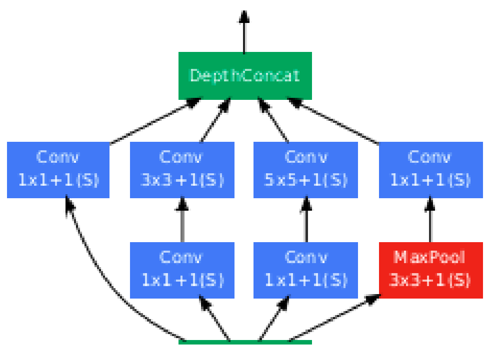
VGG



Stanford CS231

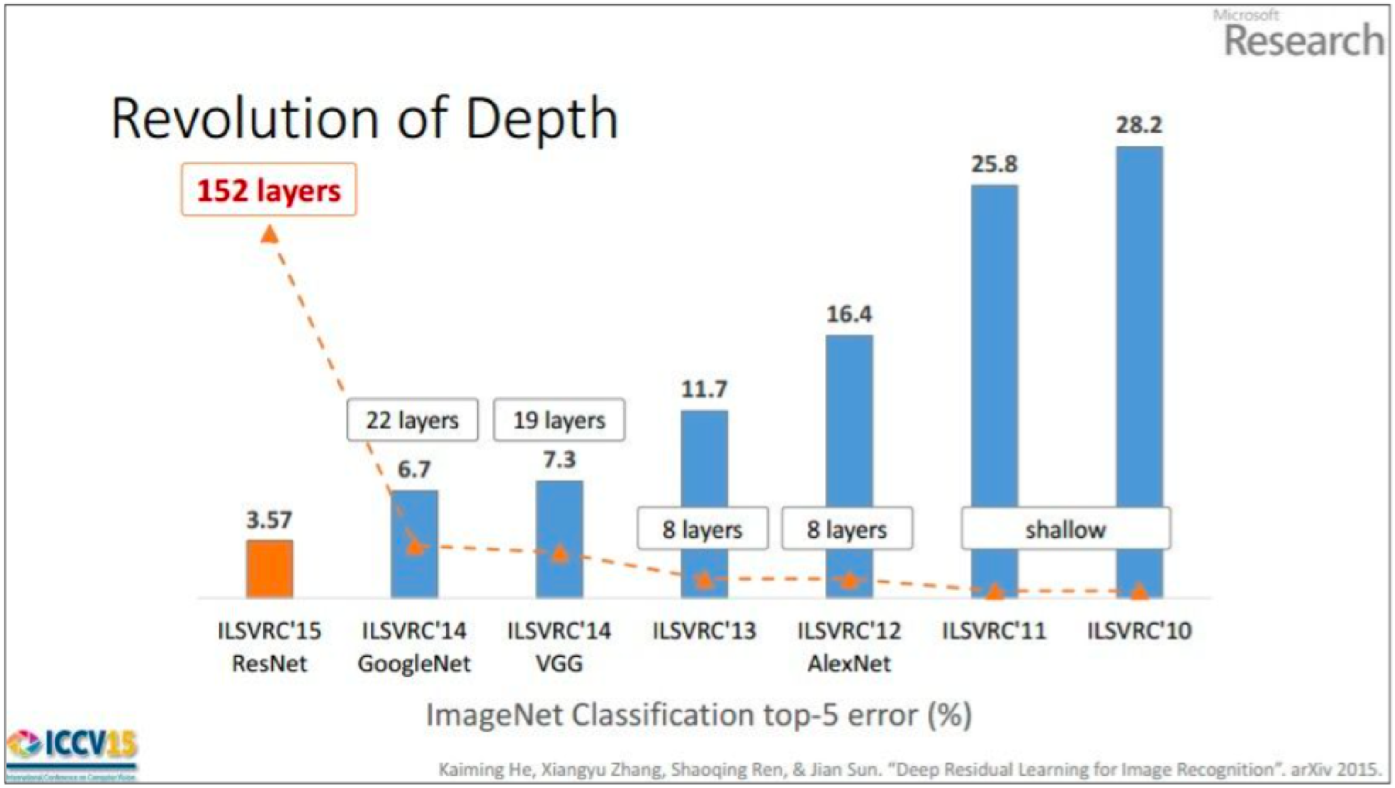
Inception, Google, 2014





Imagenet Classification

1000 kinds of objects.



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Appendix: Image to Column (Im2C)

Reduce convolution to matrix multiplication — more space but faster.

$$x'[b,i,j,\Delta i,\Delta j,c_x] = x[b,i+\Delta i,j+\Delta j,c_x]$$

$$\begin{aligned}
&y[b,i,j,c_y] \\
&= \left(\sum_{\Delta i,\Delta j,c_x} W[\Delta i,\Delta j,c_x,c_y] * x[b,i+\Delta i,\ j+\Delta j,\ c_x]\right) + B[c_y] \\
&= \left(\sum_{\Delta i,\Delta j,c_x} x'[b,i,j,\Delta i,\Delta j,c_x] * W[\Delta i,\Delta j,c_x,c_y]\right) + B[c_y] \\
&= \left(\sum_{(\Delta i,\Delta j,c_x)} x'[(b,i,j),(\Delta i,\Delta j,c_x)] * W[(\Delta i,\Delta j,c_x),c_y]\right) + B[c_y]
\end{aligned}$$

Appendix: Dilation

We can "dilate" the filter by introducing an image step size d for each step in the filter coordinates.

$$y[b,i,j,c_y] \;=\; W[\Delta i, \Delta j, c_x, c_y]x[b, i + d * \Delta i, j + d * \Delta j, c_x] + B[c_y]$$

END