Fully Convolutional Network (FCN)

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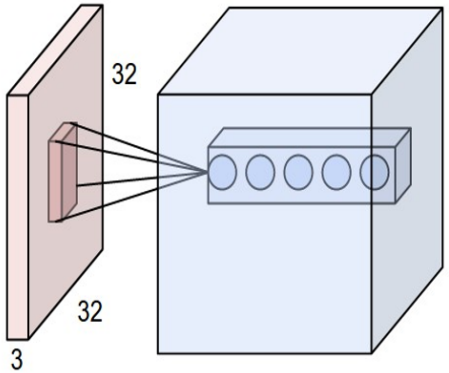
Deep Learning for Computer Vision: Review

Foundations

- Why computer vision?
- Representing images
- Convolutions for feature extraction

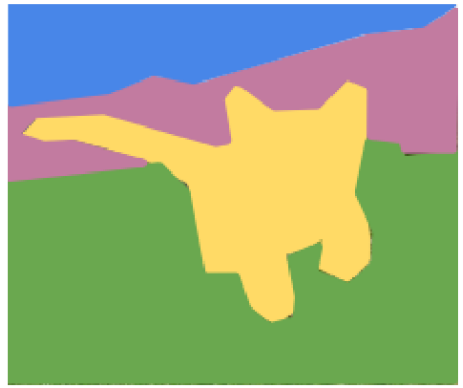
CNNs

- CNN architecture
- Application to classification: ImageNet



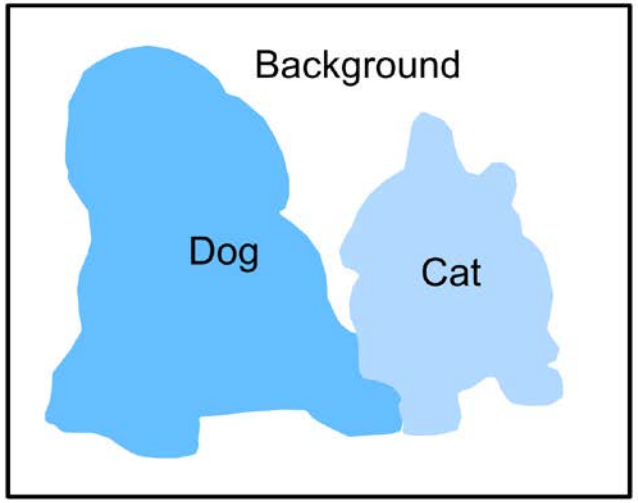
Applications

- Segmentation, object detection, image captioning
- Visualization



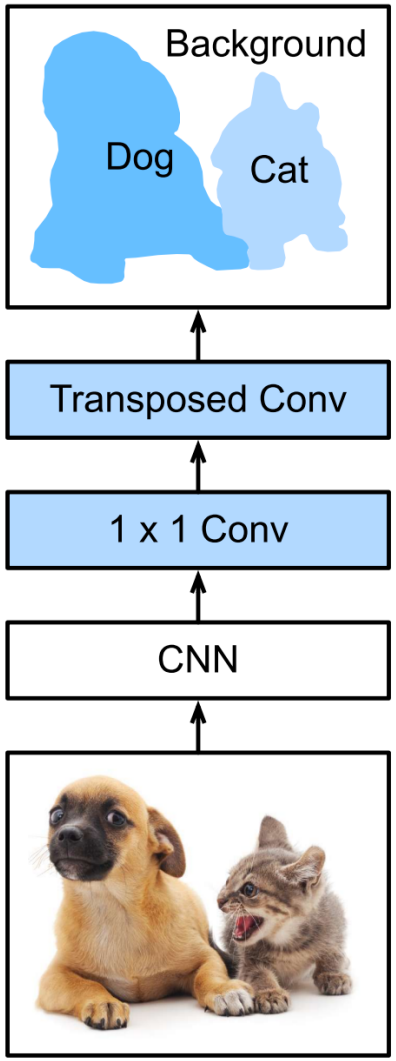
Segmentation

- Segmentation task is different from classification task because it requires predicting a class for each pixel of the input image, instead of only 1 class for the whole input.
- Classification needs to understand what is in the input (namely, the context).
- However, in order to predict what is in the input for each pixel, segmentation needs to recover not only what is in the input, but also where.
- Segment images into regions with different semantic categories. These semantic regions label and predict objects at the pixel level

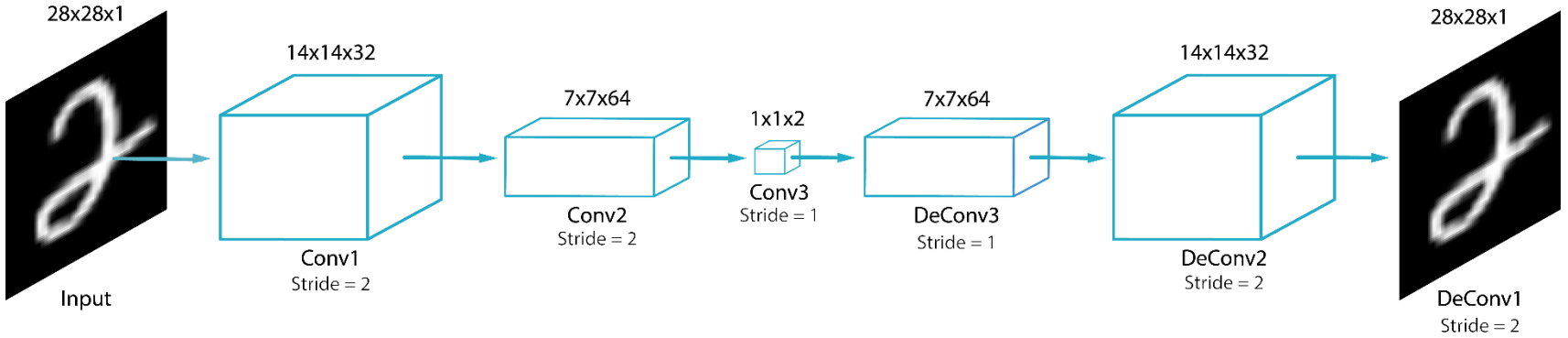


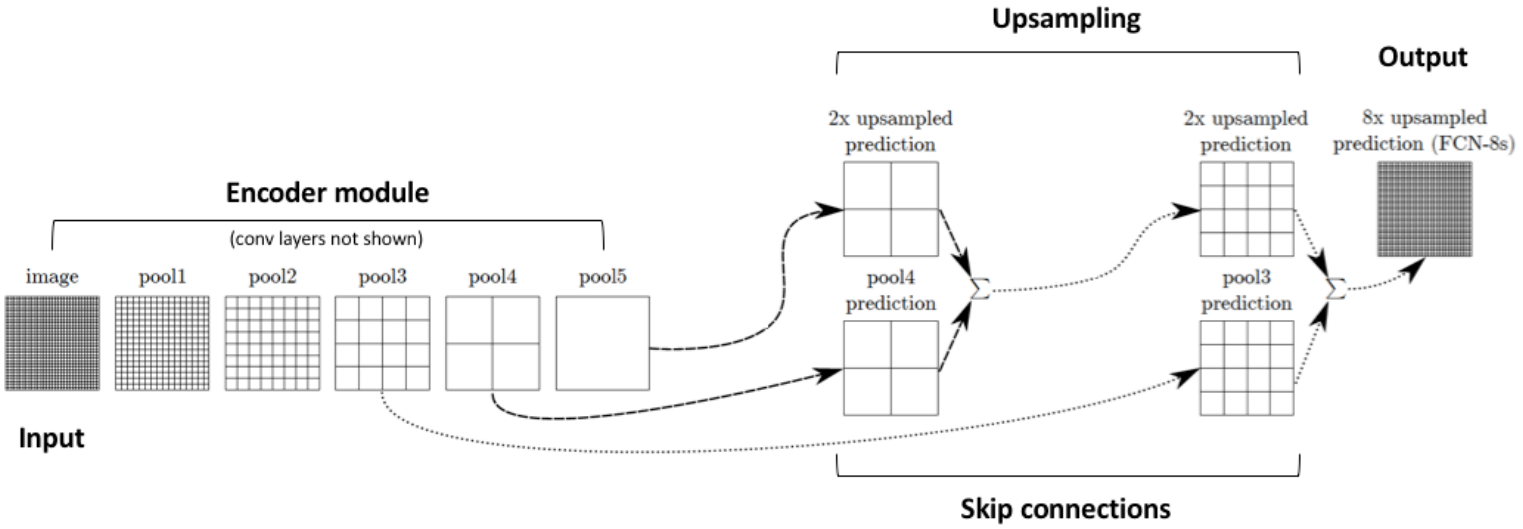
Semantic Segmentation: FCNs

- FCN uses a convolutional neural network to transform image pixels to pixel categories.
- Network designed with all convolutional layers, with down-sampling and up-sampling operations
- FCN transforms the height and width of the intermediate layer feature map back to the size of input image through the transposed convolution layer, so that the predictions have a one-to-one correspondence with input image in spatial dimension
- Given a position on the spatial dimension, the output of the channel dimension will be a category prediction of the pixel corresponding to the location.



From CAE to FCN

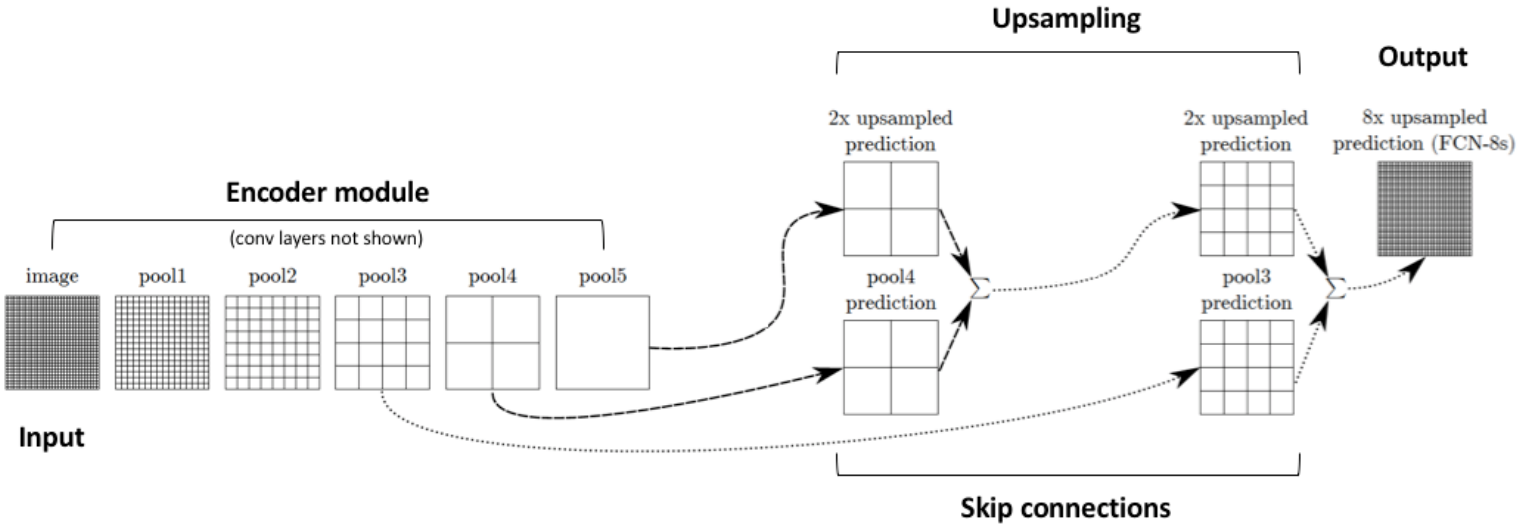




J. Long, E. Shelhamer, T. Darrell, Fully Convolutional Networks for Semantic Segmentation, CVPR 2015

Fully Convolutional Networks (FCNs)

- To obtain a segmentation map (output), segmentation networks usually have 2 parts
  - Downsampling path: capture semantic/contextual information
  - Upsampling path: recover spatial information
- The downsampling path is used to extract and interpret the context (what), while the upsampling path is used to enable precise localization (where).
- Furthermore, to fully recover the fine-grained spatial information lost in the pooling or downsampling layers, we often use skip connections.
- Network can work regardless of the original image size, without requiring any fixed number of units at any stage.

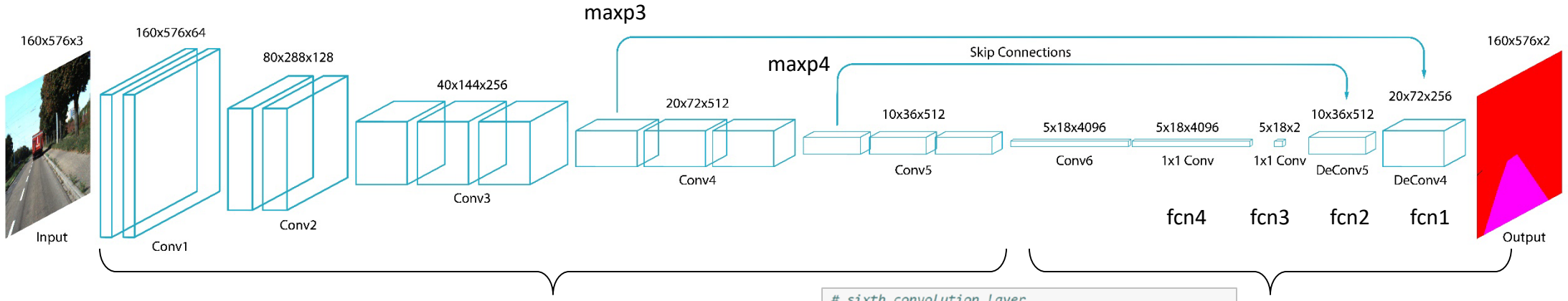


Skip Connection

- A skip connection is a connection that bypasses at least one layer.
- Here, it is often used to transfer local information by concatenating or summing feature maps from the downsampling path with feature maps from the upsampling path.
- Merging features from various resolution levels helps combining context information with spatial information.

Segmented (Labeled) Images

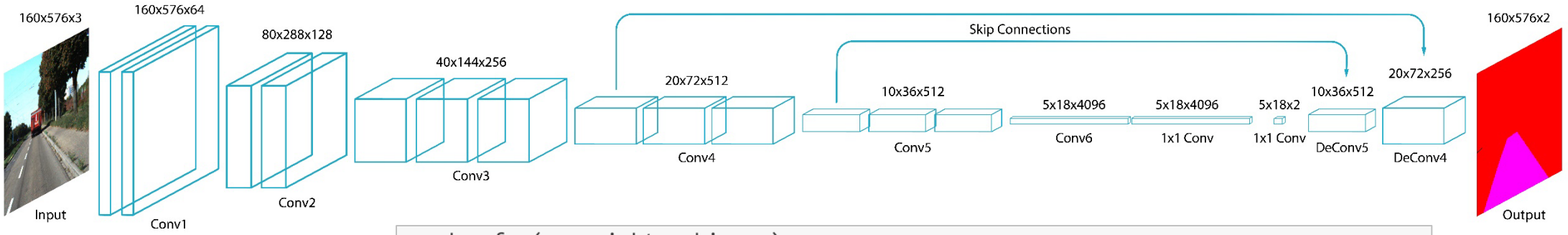
FCN Architecture




```
vgg16_weights = model.get_weights()

weights = {
    'conv1_1' : tf.constant(vgg16_weights[0]),
    'conv1_2' : tf.constant(vgg16_weights[2]),

    'conv2_1' : tf.constant(vgg16_weights[4]),
    'conv2_2' : tf.constant(vgg16_weights[6]),

    'conv3_1' : tf.constant(vgg16_weights[8]),
    'conv3_2' : tf.constant(vgg16_weights[10]),
    'conv3_3' : tf.constant(vgg16_weights[12]),

    'conv4_1' : tf.constant(vgg16_weights[14]),
    'conv4_2' : tf.constant(vgg16_weights[16]),
    'conv4_3' : tf.constant(vgg16_weights[18]),

    'conv5_1' : tf.constant(vgg16_weights[20]),
    'conv5_2' : tf.constant(vgg16_weights[22]),
    'conv5_3' : tf.constant(vgg16_weights[24]),
}
```

```
# sixth convolution layer
conv6 = tf.layers.conv2d(maxp5,
                         filters = 4096,
                         kernel_size = 7,
                         padding = 'SAME',
                         activation = tf.nn.relu)

# 1x1 convolution layers
fcn4 = tf.layers.conv2d(conv6,
                         filters = 4096,
                         kernel_size = 1,
                         padding = 'SAME',
                         activation = tf.nn.relu)
fcn3 = tf.layers.conv2d(fcn4,
                         filters = 2,
                         kernel_size = 1,
                         padding = 'SAME')

# Upsampling layers
fcn2 = tf.layers.conv2d_transpose(fcn3,
                                  filters = 512,
                                  kernel_size = 4,
                                  strides = (2, 2),
                                  padding = 'SAME')

fcn1 = tf.layers.conv2d_transpose(fcn2 + maxp4,
                                  filters = 256,
                                  kernel_size = 4,
                                  strides = (2, 2),
                                  padding = 'SAME')

output = tf.layers.conv2d_transpose(fcn1 + maxp3,
                                    filters = 2,
                                    kernel_size = 16,
                                    strides = (8, 8),
                                    padding = 'SAME')
```

Segmentation Result




```
pred = fcn(x, weights, biases)
logits = tf.reshape(pred, (-1, 2))
labels = tf.reshape(y, (-1, 2))

loss = tf.nn.softmax_cross_entropy_with_logits(logits = logits, labels = labels)
loss = tf.reduce_mean(loss)
```