CS 4824/ECE 4424: Convolutional Neural Networks

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Large Networks

- What kind of neural networks can be used for large or variable length input vectors (e.g., time series)

- Common networks
  - Convolutional networks
  - Recursive networks
  - Recurrent networks

Convolutions for feature extraction

- In neural networks
  - A convolution denotes the linear combination of a subset of units based on a specific pattern of weights.

$$a_j = \sum_i w_{ji} z_i$$

  - Convolutions are often combined with an activation function to produce a feature

$$z_j = h(a_j) = h\left(\sum_i w_{ji} z_i\right)$$

Convolution Neural Network (CNN)

- A **CNN** refers to any network that consists of an **alternation of convolution and pooling layers**, where **some of the convolution weights are shared**
- Architecture:

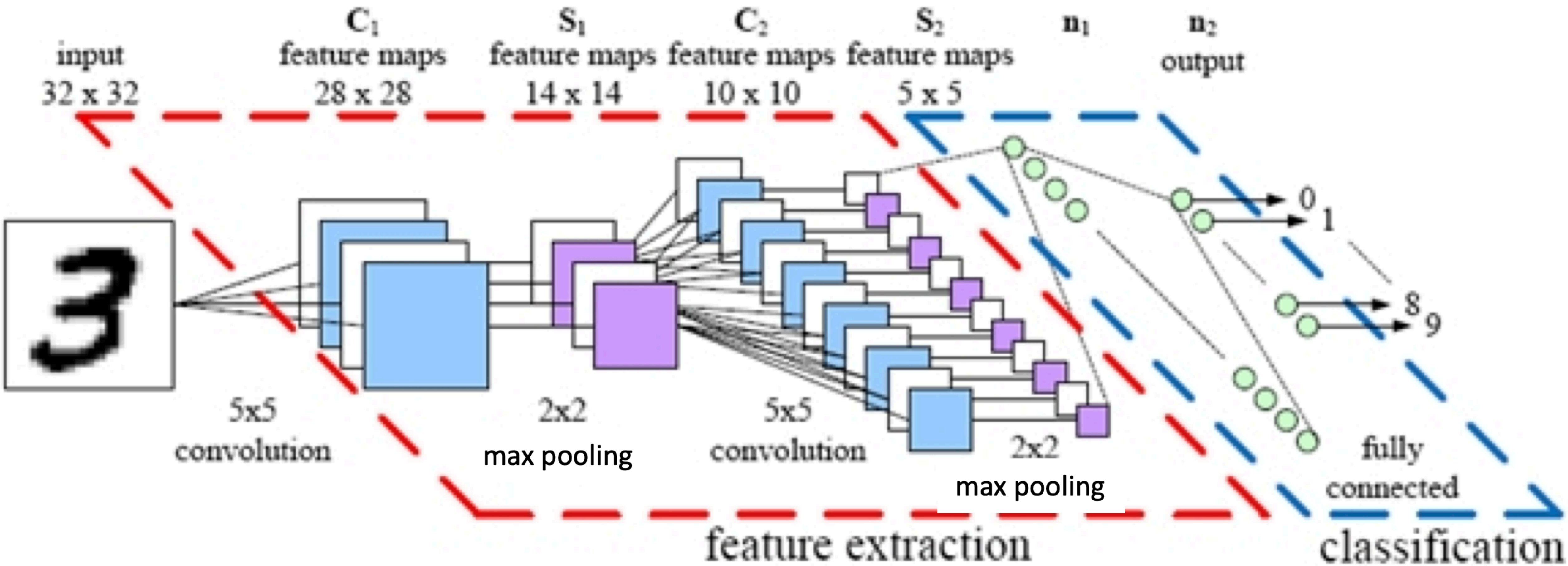
Pooling

- Pooling: **commutative** mathematical operation that combines several units

- Examples:
  - max, sum, product, average, Euclidean norm, etc.

- Commutative property (order does not matter):
  - $\max(a, b) = \max(b, a)$

Digit Recognition



Benefits of CNN

- Sparse interactions
  - Fewer connections
- Parameter sharing
  - Fewer weights
- Locally equivariant representation
  - Locally invariant to translations
  - Handle inputs of varying length

Parameters

- # **of filters**: integer indicating the #of filters applied to each window

- **kernel size**: tuple (width, height) indicating the size of the window
- **Stride**: tuple (horizontal, vertical) indicating the horizontal and vertical shift between each window

- **Padding**: “valid” or ”same”. Valid indicates no input padding. Same indicates that the input is padded with a border of zeros to ensure that the output has the same size as the input

Examples

Training CNN

- Convolutional neural networks are trained in the same way as other neural networks through backpropagation
  - AdaGrad, RMSprop, Adam
- Weight sharing:
  - Combine gradients of shared weights into a single gradient

Architecture design

- What is the preferred filter size?
-]VGG (Visual Geometry Group at Oxford, 2014): stack of small filters is often preferred to single large filter
  - Fewer parameters
  - Deeper network
- Schematic:

Residual Networks

- **Idea**: Addressing vanishing gradient problem by introducing residual connections (a.k.a. skip connections) to shorten paths (He et al. 2015)

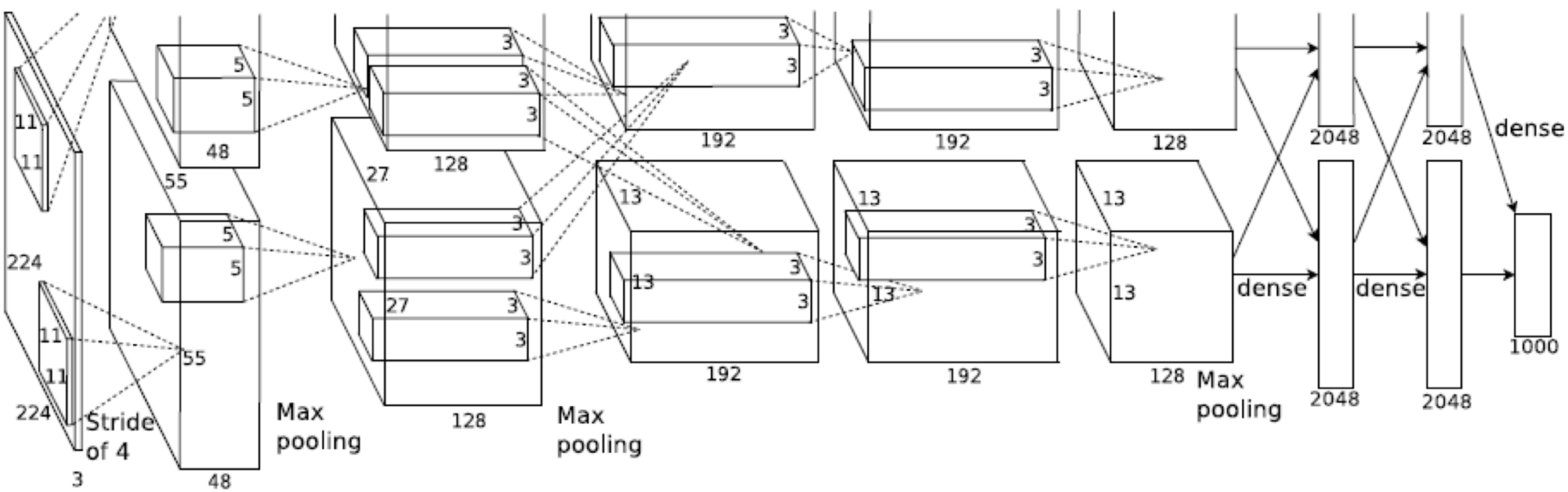
- Schematic:

Applications

- Speech Recognition
- **Image recognition**
- Machine translation
- Control
- …
- Data with sequential, spatial or tensor patterns

Image Recognition

- Convolutional Neural Network
  - With rectified linear units and dropout
  - Data augmentation for transformation invariance



ImageNet Breakthrough

- Results: ILSVRC-2012
  - Krizhevsky, Sutskever, Hinton

Model	Top-1 (val)	Top-5 (val)	Top-5 (test)
SIFT + FVs [7]	—	—	*26.2%*
1 CNN	40.7%	18.2%	—
5 CNNs	38.1%	16.4%	**16.4%**
1 CNN*	39.0%	16.6%	—
7 CNNs*	36.7%	15.4%	**15.3%**

Table 2: Comparison of error rates on ILSVRC-2012 validation and test sets. In *italics* are best results achieved by others. Models with an asterisk* were "pre-trained" to classify the entire ImageNet 2011 Fall release. See Section 6 for details.

ImageNet Breakthrough

- From Krizhevsky, Sutskever, Hinton