

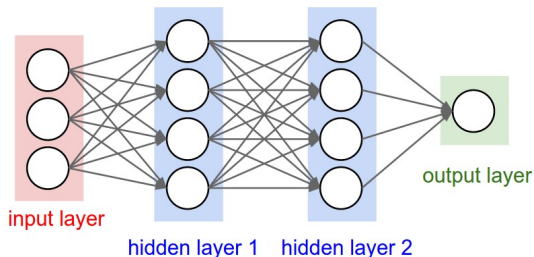
Convolutional Neural Networks

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Recall



- ▶ Input layer: single vector of feature inputs.
- ▶ Hidden layer(s): sets of neurons with nonlinear activation, fully connected by weights (with biases) to other layers.
- ▶ Output layer: single vector of output scores.

Image source: Stanford University

Problems

- ▶ Doesn't scale well to large features, such as images.
- ▶ Speech and images are rich in structure (e.g. hierarchy). In the case of images, how can we utilize the structure to our advantage?
- ▶ Take advantage of the properties of images to create a new network.

Convolutional Layers

- ▶ Recall: neurons match inputs to patterns.
- ▶ Create $w \times h$ templates for $w \times h$ receptive fields centered at (x, y) locations in the image, with stride s (usually small) along each dimension.
 - ▶ Each receptive field is hence *local*.
- ▶ Match the template to the field, and compute a score via the *dot product*.
- ▶ Construct a new image of the activation of the scores.

Pooling Layers

- ▶ Reduces the number of parameters (and hence computations).
- ▶ Controls overfitting: intuitively, allows for translational invariance.
- ▶ Compute the maximum score for each $w \times h$ subimage across the image (overlap possible).
- ▶ Construct a new, smaller image of the maximum scores.
- ▶ Common variations of the sizes include 2×2 and 2×3 (with overlapping).

Fully-Connected Layers

- ▶ These layers are identical to the hidden layers as before: sets of neurons with nonlinear activation (usually ReLU), fully connected by weights (with biases) to other layers.
- ▶ Input from the final convolutional layer, consisting of transformed and smaller features.

Aside: Convolution

- ▶ Why are these called convolutional neural networks?
- ▶ Recall the convolutional layers in the network, which perform template-matching; with stride 1, this can be viewed as a convolution over the image.

Backpropagation

- ▶ Backpropagation is performed in a manner identical to fully-connected neural networks (i.e. as before).

Data Augmentation

- ▶ Important to include larger sets of training data.
- ▶ Ex: horizontal/vertical flips, rotations, resizing, cropping, changes in contrast/brightness, and/or distortions.

AlexNet

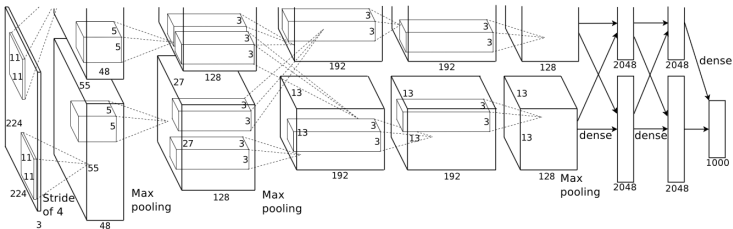


Image source: Conference on Neural Information Processing Systems

Example

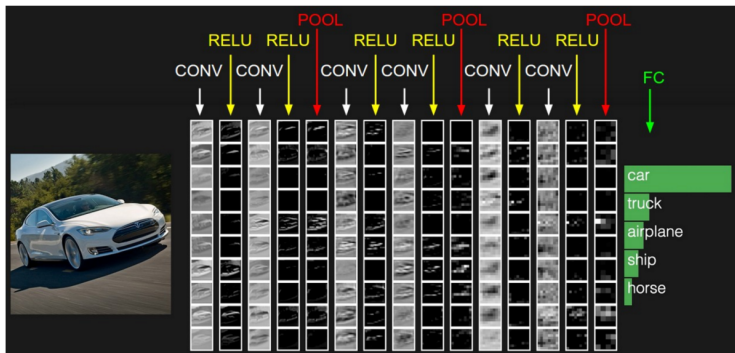


Image source: Stanford University

Notebook

- ▶ Today's notebook will work through an example of convolutional neural networks.

References

- ▶ *Deep Convolutional Neural Nets*
- ▶ *Convolutional Neural Networks for Visual Recognition*