Convolutional Neural Networks

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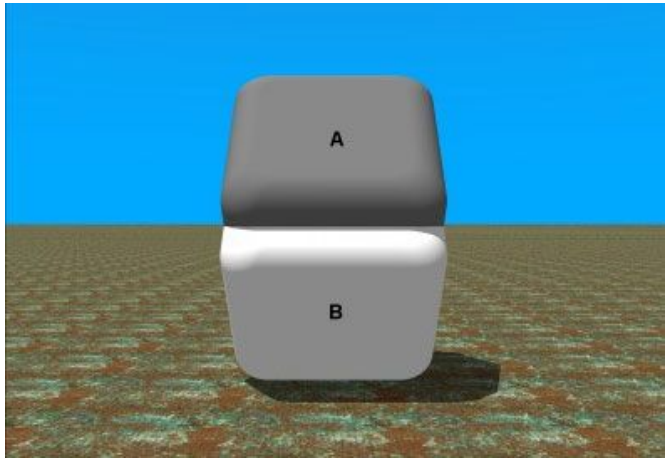
Interpreting Images

- Images are very big structures:

Deep Networks for Image Recognition

- Images are composed of large numbers of pixels
- A particular pixel value can vary a lot:
  - Color, illumination
- Objects can vary a lot
  - Size, orientation, perspective

Individual pixels are irrelevant…



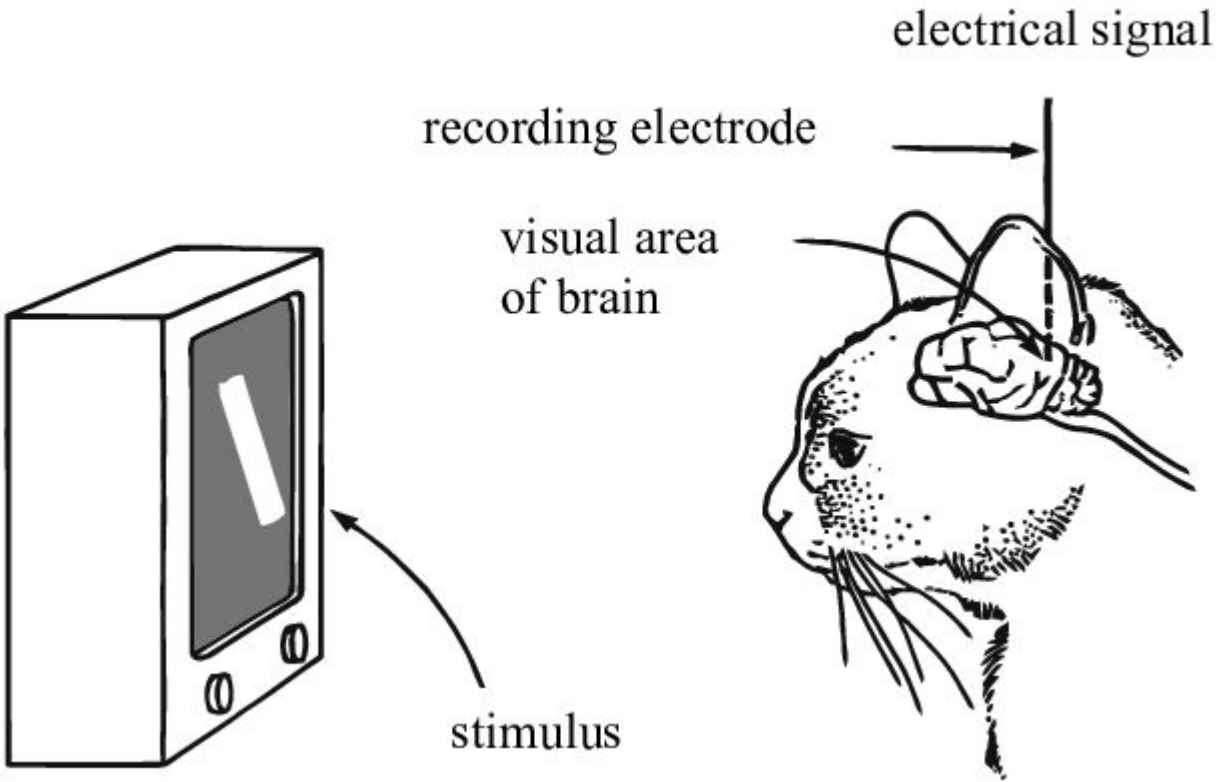
http://brainden.com/color-illusions.htm

Deep Networks for Image Recognition

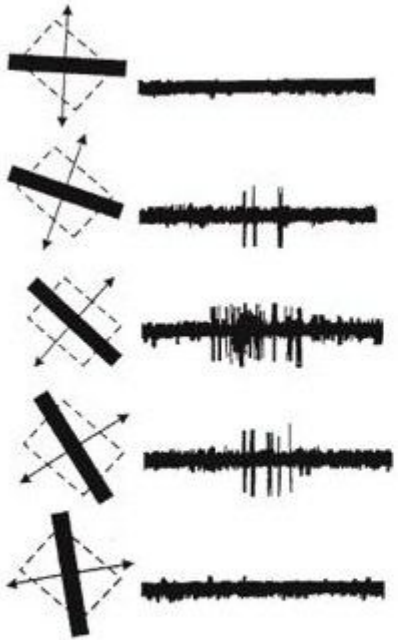
- 1920 (rows) x 1020 (columns) x 3 (channels = RGB) is almost 6 million inputs
- If the next dense layer has 1000 units, then we would have 6 billion parameters!

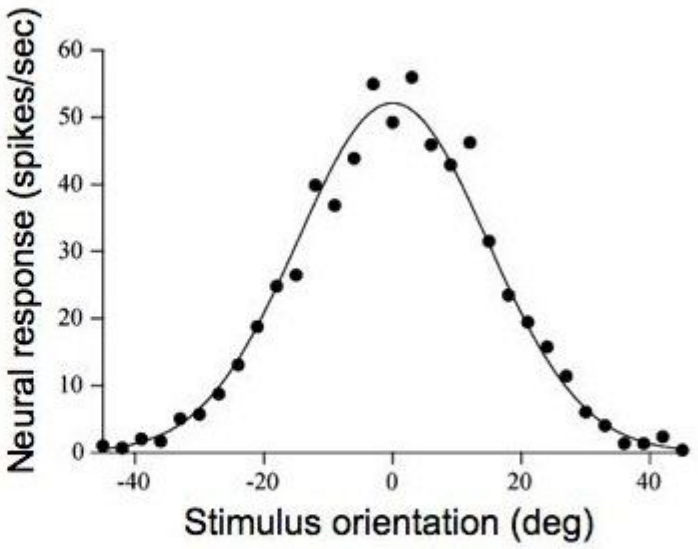
Need lots of examples and lots of training time. How do we get beyond this?

Hubel and Wiesel (1968)



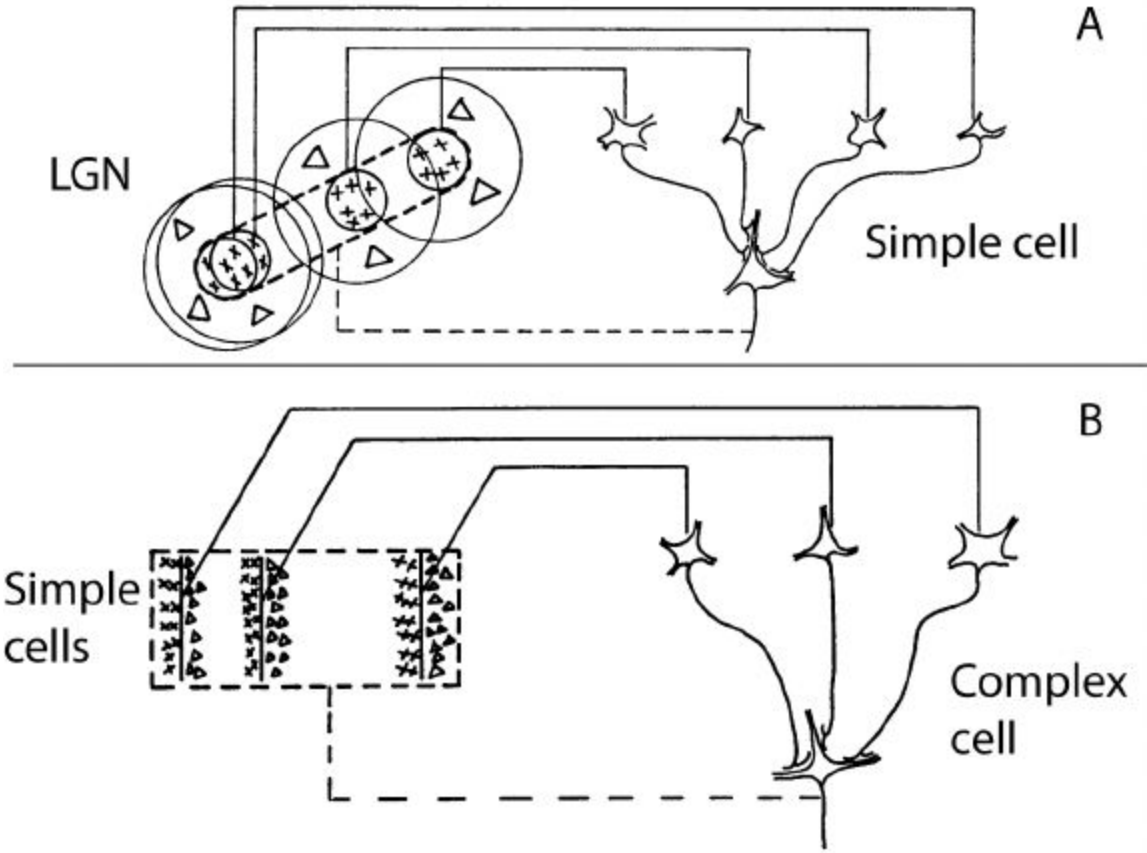
Orientation Sensitivity

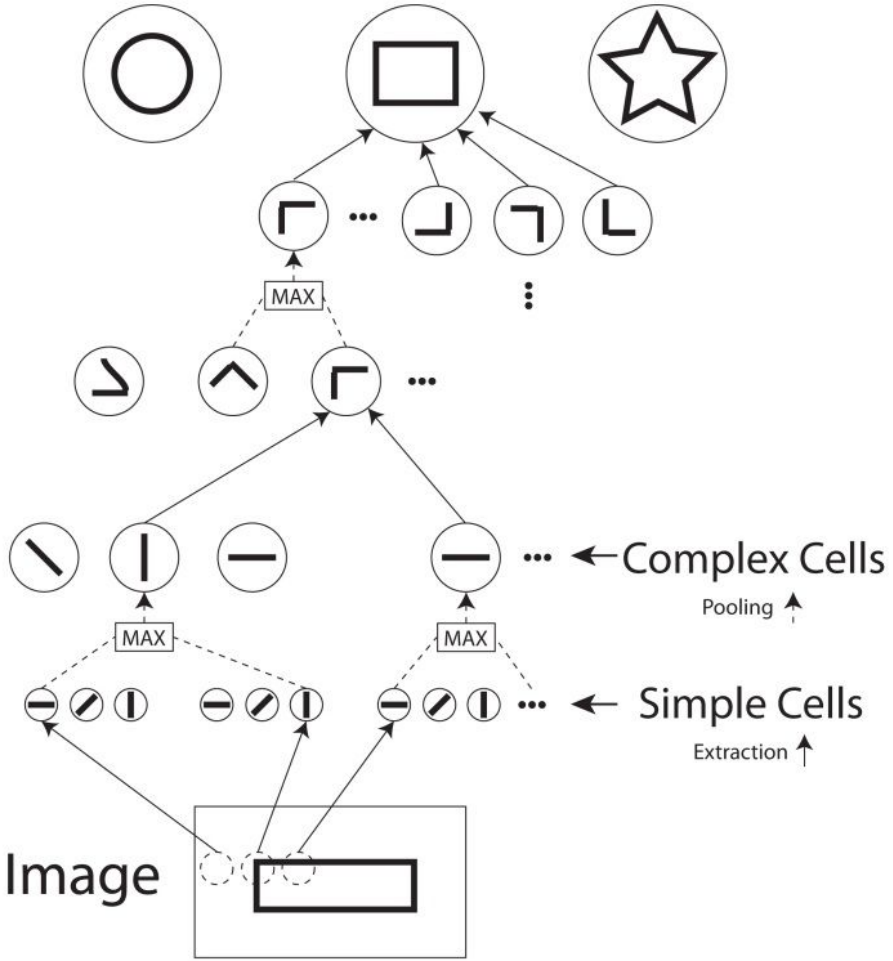




Hubel & Wiesel, 1968

Complex Features Formed from Simple Ones



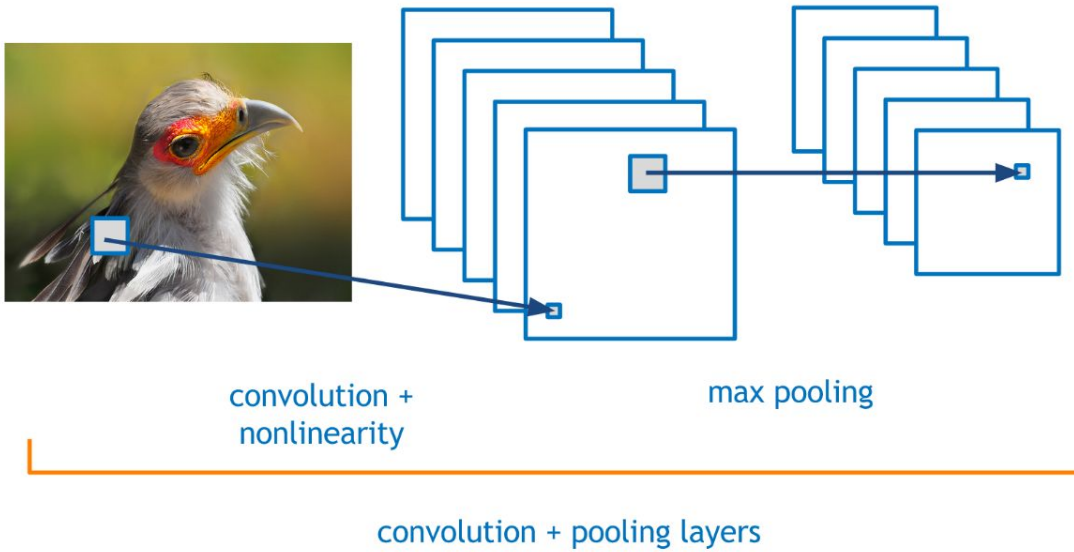


https://www.intechopen.com/books/visual-cortex-current-status-and-perspectives/models-of-information-processing-in-the-visual-cortex

Operator Types

- Feature detection: recognize some pattern over a small grid of inputs
  - Convolution
- Pooling: does there exist some pattern within the grid of inputs?
  - Max
- Scaling: Allows simple feature detection and pooling to apply at multiple visual scales

Local Operators



wp.flickr.net

Local Operators

Multiple stacked modules consisting of pattern recognition (convolution), pooling (max) and scaling (striding)

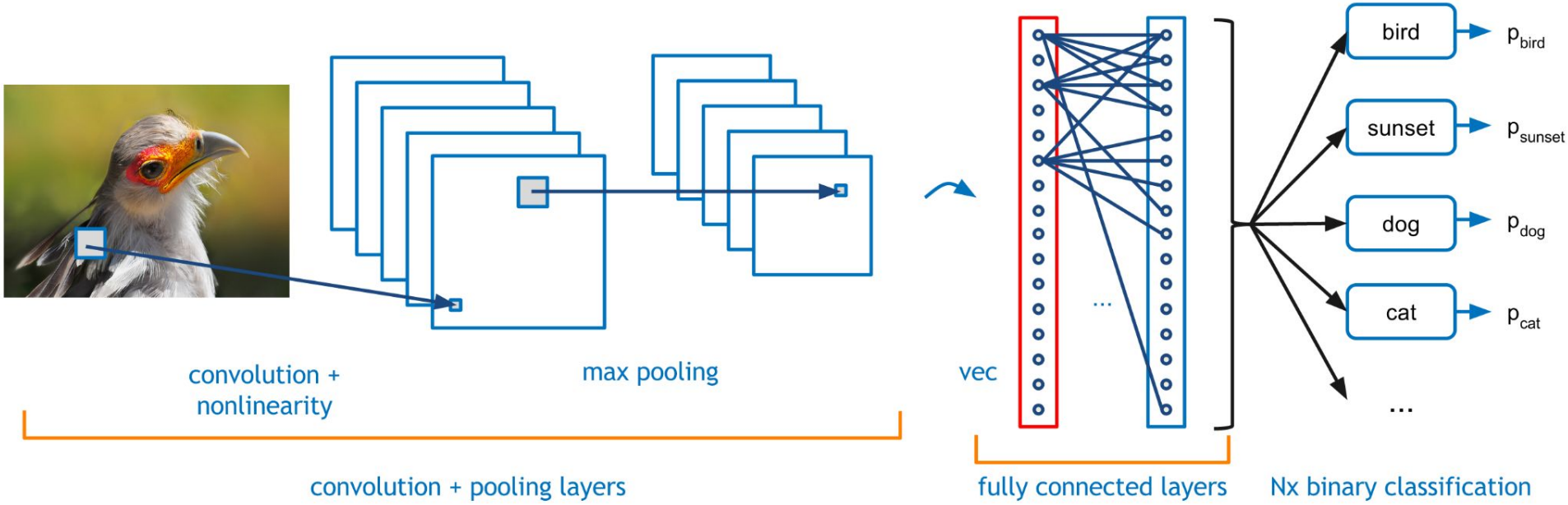
- With each module, our representation becomes more and more abstract
  - Ultimately: feathers, eyes, beaks …
  - All have specific visual patterns, though there may be many variations of each
- Putting these larger scale features together: how do we handle the big variations in positioning of eyes relative to beaks (and other features)?

Beyond the Primitives

How should the primitives be combined to form more of a semantic representation (dog, cat, grandma, etc.)?

- After computing the primitives in the first layers of our deep network, employ dense layers to allow for arbitrary combinations of the primitives

Combining Local Operators to Recognize Global Patterns



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Simple Image Recognition Architecture

- Multiple modules of convolution, pooling and scaling
- “Flatten” the feature representation
- Multiple layers of densely connected neurons
- Final layer:
  - Compute a score for each class that we are recognizing
  - Compute a softmax over the scores: yields class probabilities

Representation Across the Cortex

- Neighboring neurons tend to be responsive to similarly oriented edges
- Both eyes project to visual cortex
  - At these early stages: information from both eyes is not integrated
- Not shown: different parts of the retina are also covered