CS 540 Introduction to Artificial Intelligence
Deep Learning III

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Announcements

- **HW7:** Due next Tuesday
- **Midterm:** grading completed

- **Class roadmap:**
  - Today:
    - A bit more on Deep Learning
    - Summary of neural networks
  - Next:
    - Search
    - Games

Artificial Intelligence

Outline

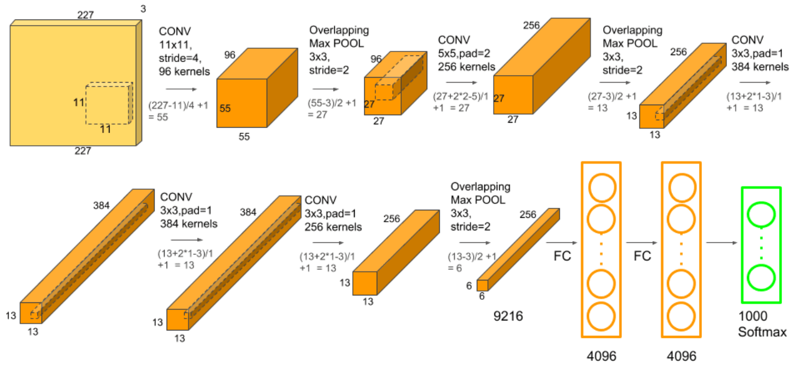
- CNNs with more layers: ResNets
  – Layer problems, residual connections, identity maps
- Data Augmentation & Regularization
  – Expanding the dataset, avoiding overfitting

Last Time: CNNs

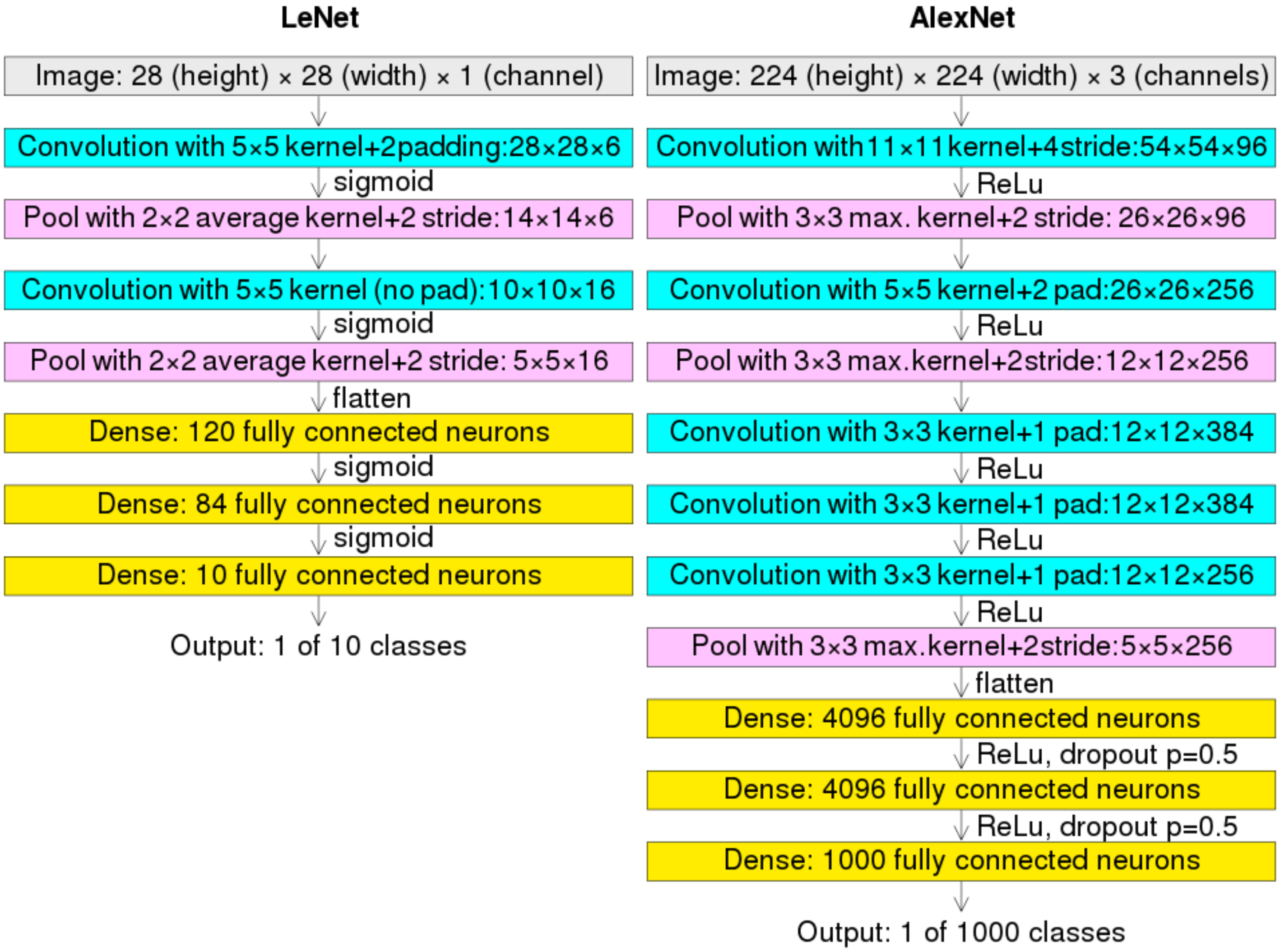
Convolutional Neural Networks:

- **Components**: convolutional layers, pooling layers (recall kernels, channels, strides, padding)
- **Architectures**: LeNet, AlexNet, VGG

- Trend: bigger, deeper.

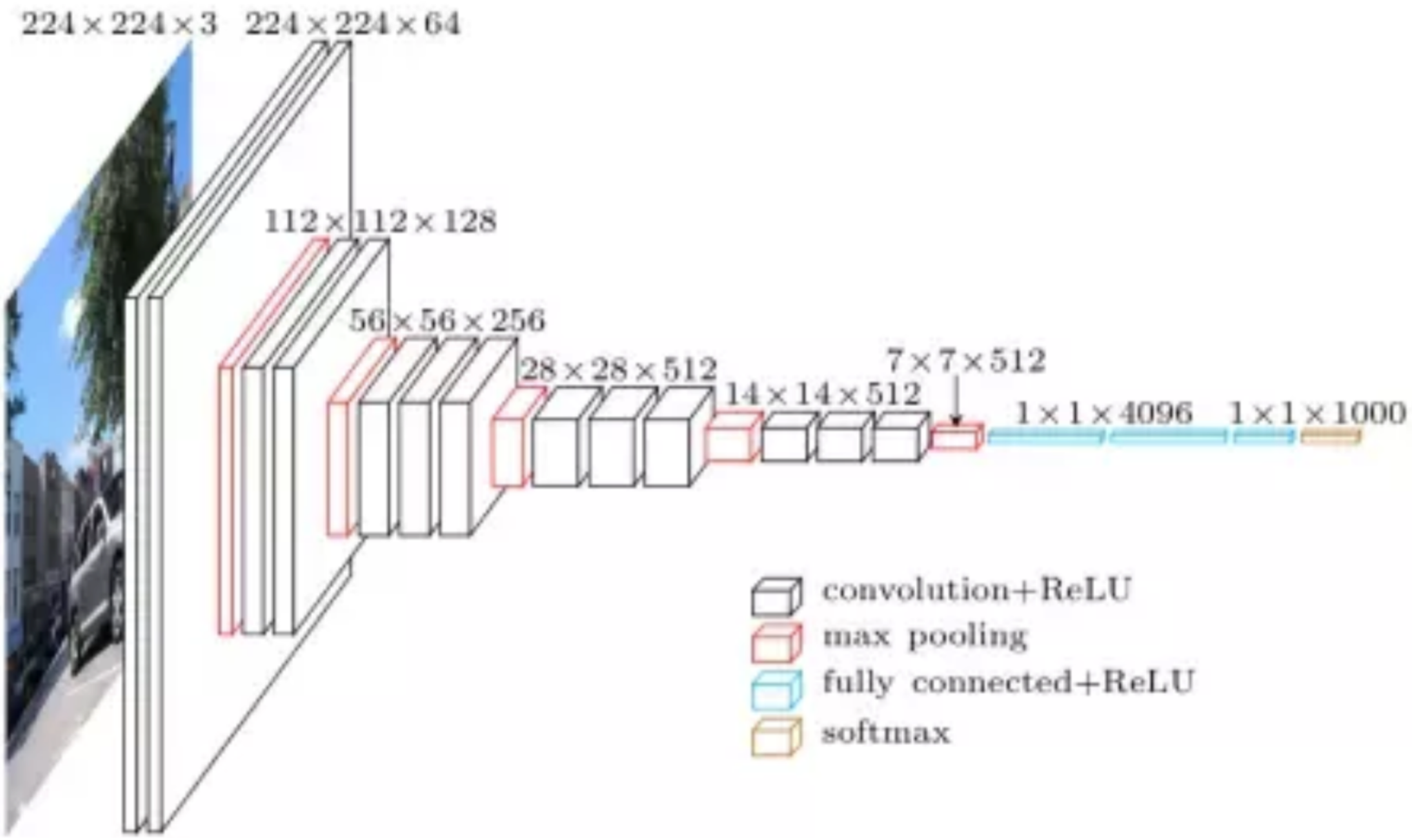


Credit: Mathworks



Credit: Wikipedia

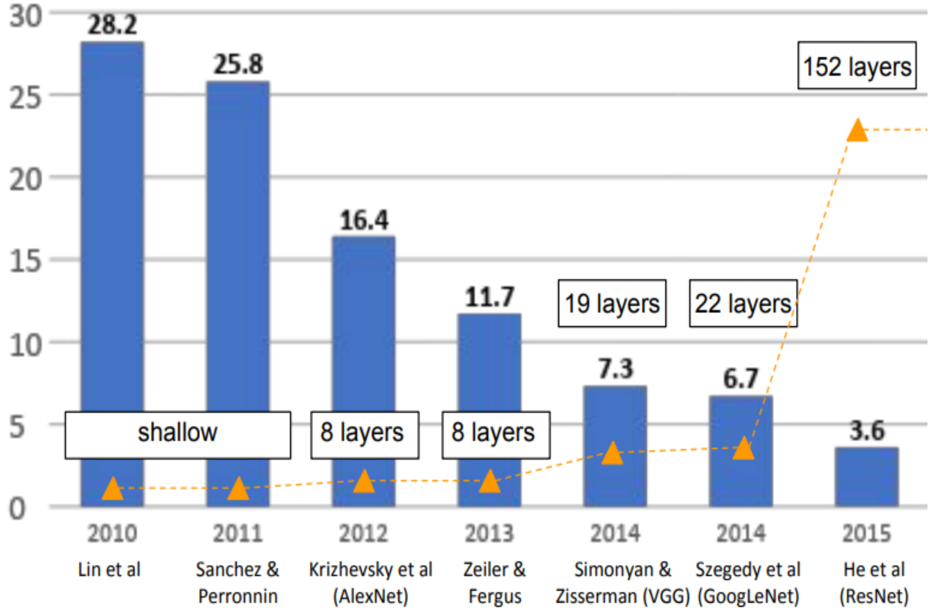
VGG



224 × 224 × 3
224 × 224 × 64
112 × 112 × 128
56 × 56 × 256
28 × 28 × 512
14 × 14 × 512
7 × 7 × 512
1 × 1 × 4096
1 × 1 × 1000
convolution+ReLU
max pooling
fully connected+ReLU
softmax

Evolution of CNNs

ImageNet competition (error rate)



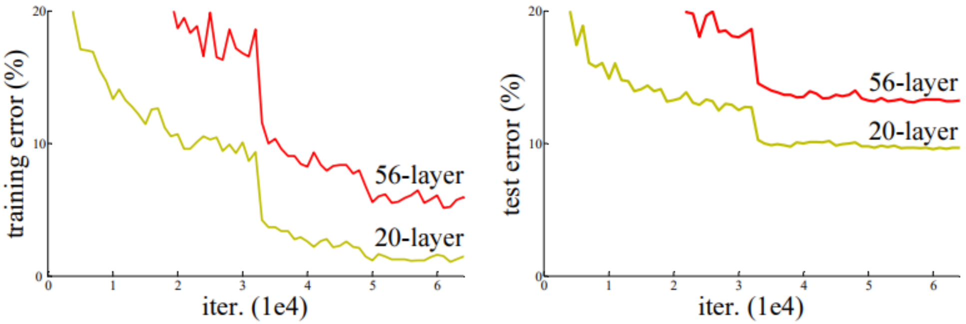
Credit: Stanford CS 231n

Simple Idea: Add More Layers

AlexNet 8 layers, VGG: 19 layers. **Add more layers**... sufficient?

- No! Some problems:
  - i) Vanishing gradients: more layers ➔ more likely
  - ii) Instability: can't even guarantee we learn **identity** map $f(x) = x$

Reflected in training error:

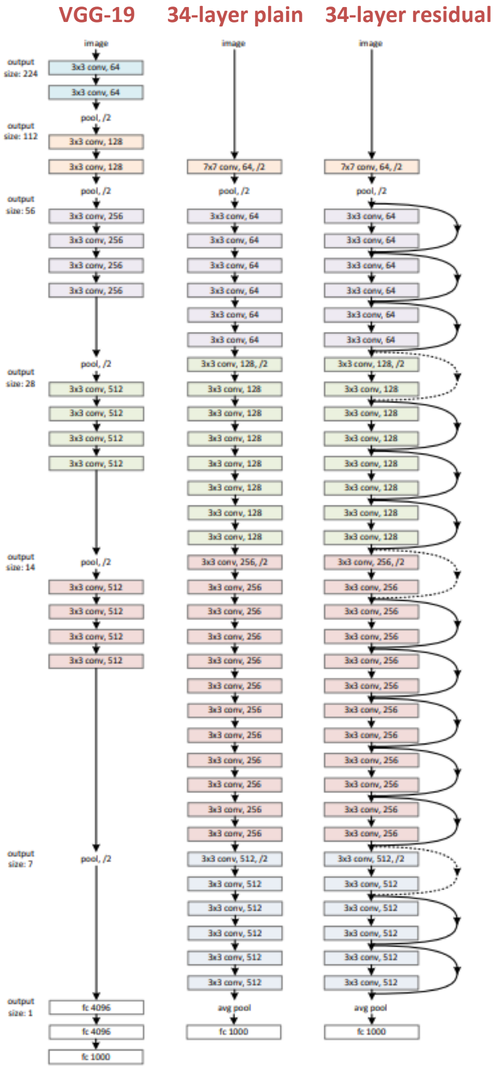


He et al: "Deep Residual Learning for Image Recognition"

ResNet Architecture

Idea: Residual (skip) connections help make learning easier

- Right: Example architecture
- Note: residual connections
  - Every two layers for ResNet34
- **Vastly better** performance
  - No additional parameters!
  - Records on many benchmarks



He et al: “Deep Residual Learning for Image Recognition”

More on ResNets

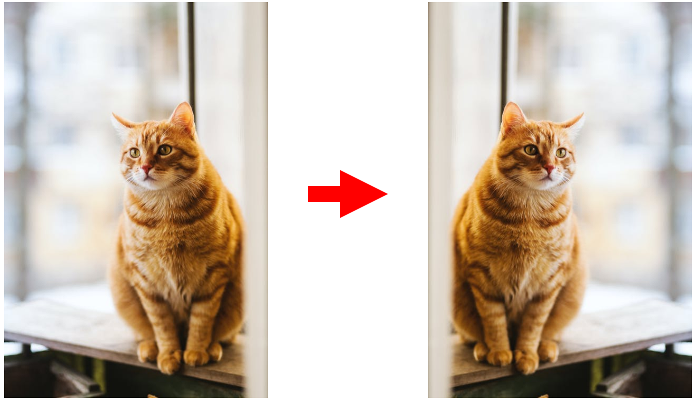
Idea: Residual (skip) connections help make learning easier

- Alleviate vanishing gradient issue
- More paths in computation graph: better information flow

Data Concerns

What if we don't have a lot of data?

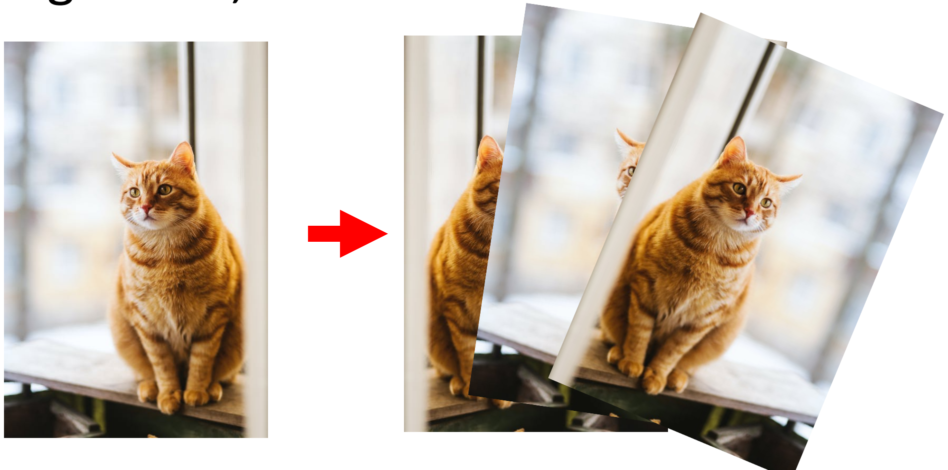
- We risk overfitting
- Avoiding overfitting: **regularization** methods
- Another way: Data Augmentation



Data Augmentation

Augmentation: transform + add new samples to dataset

- Transformations: based on domain
- Idea: build **invariances** into the model
  - **Ex**: if all images have same alignment, model learns to use it
- Keep the label the same!



Transformations

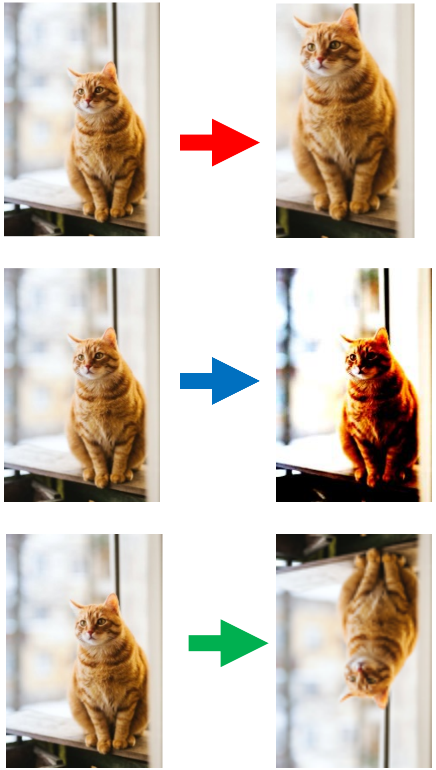
Examples of transformations for images

- **Crop** (and zoom)
- **Color** (change contrast/brightness)
- **Rotations+** (translate, stretch, shear, etc)

Many more possibilities. Combine as well!

Q: how to deal with this at **test time**?

- A: transform, test, average

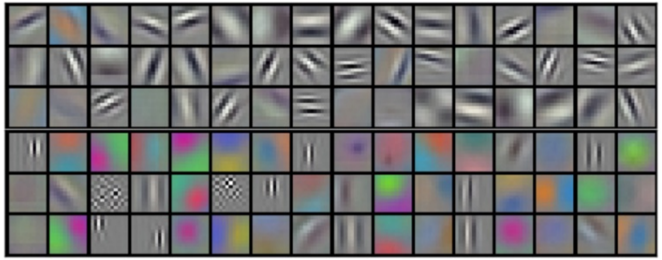


Importance of Augmentation

Data augmentation is critical for top performance!

- You should use it!
- **AlexNet**: used (many papers re-used as well)
  - Random crops, rotations, flips. **2048x** expansion!
  - Color augmentation via PCA. **1% error rate reduction**

Krizhevsky et al: “ImageNet Classification with Deep Convolutional Neural Networks”



Summary

- Intro to deeper networks (ResNets)
  - Dealing with problems by adding skip connections
- Data augmentation

Acknowledgements: Inspired by materials by Fei-Fei Li, Ranjay Krishna, Danfei Xu (Stanford CS231n)