Intro to Neural Networks

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CNNs

Convolutional Networks

A Problem of Scalability

- How many parameters in this network?
- Do we really need to learn all these parameters?

3 x 224 x 224 = ~150k pixels

Figure courtesy of Robert Bond

Deep Neural Network

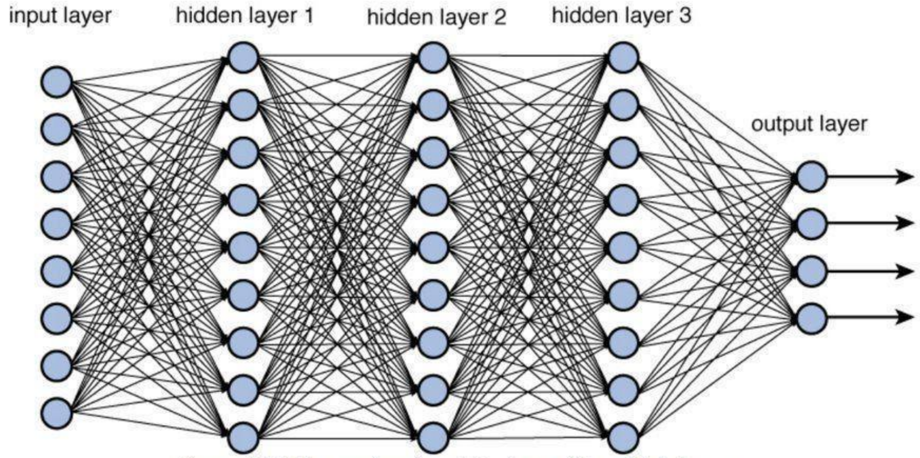


Figure 12.2 Deep network architecture with multiple layers.

Figure courtesy of Ravindra Parmar

Structure in Images

- Interesting images have:
  - Locality of information.
  - Spatial invariance.

Figure courtesy of Robert Bond

vs.

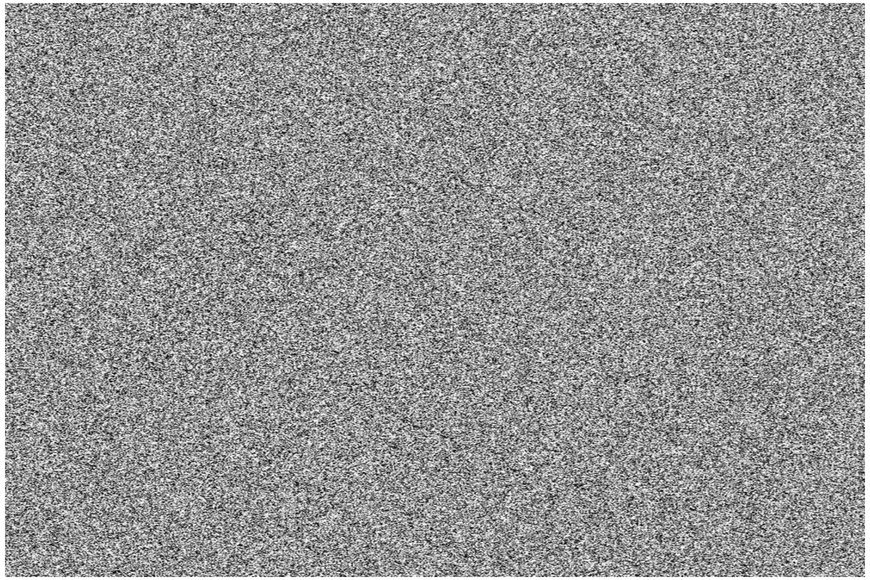


Figure courtesy of Jorge Stolfi

Convolutional Filters

- Instead of learning a mesh of all possible parameters, let's learn local descriptors ***(kernels or filters)*** that can be reused across the image!

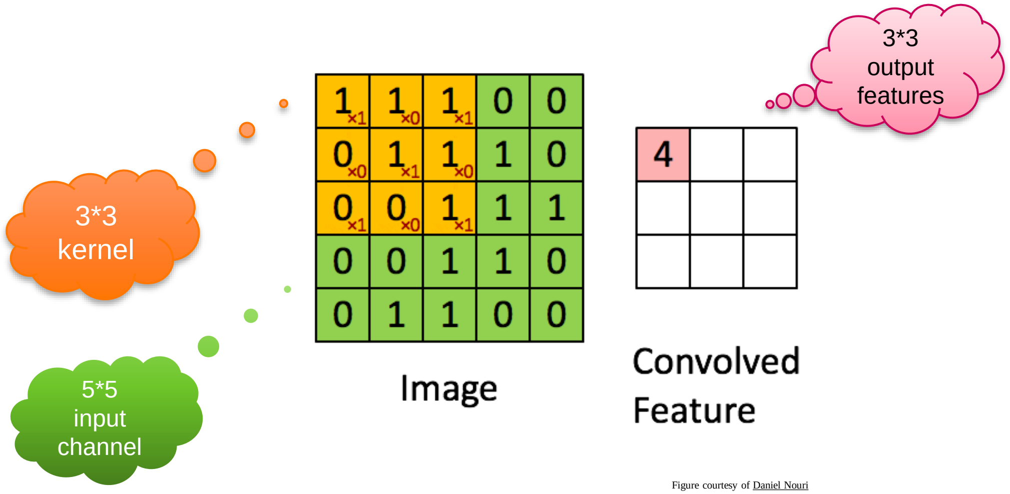


Figure courtesy of Daniel Nouri

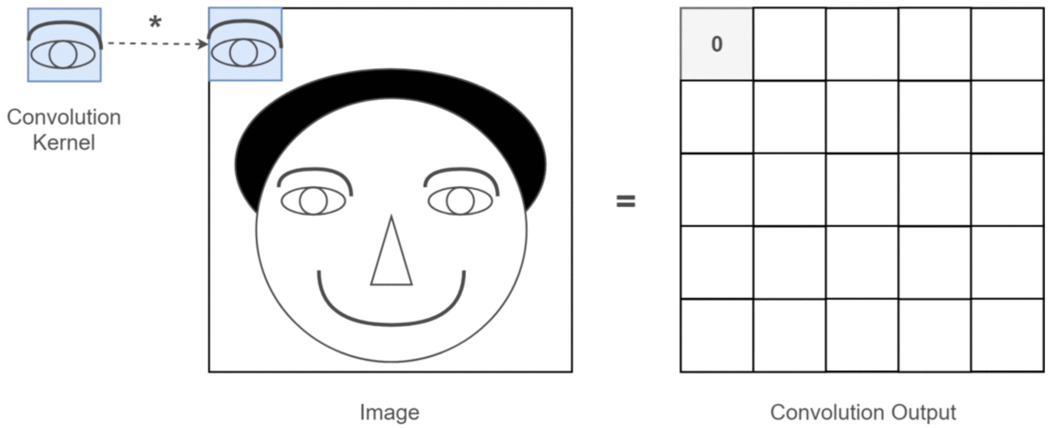
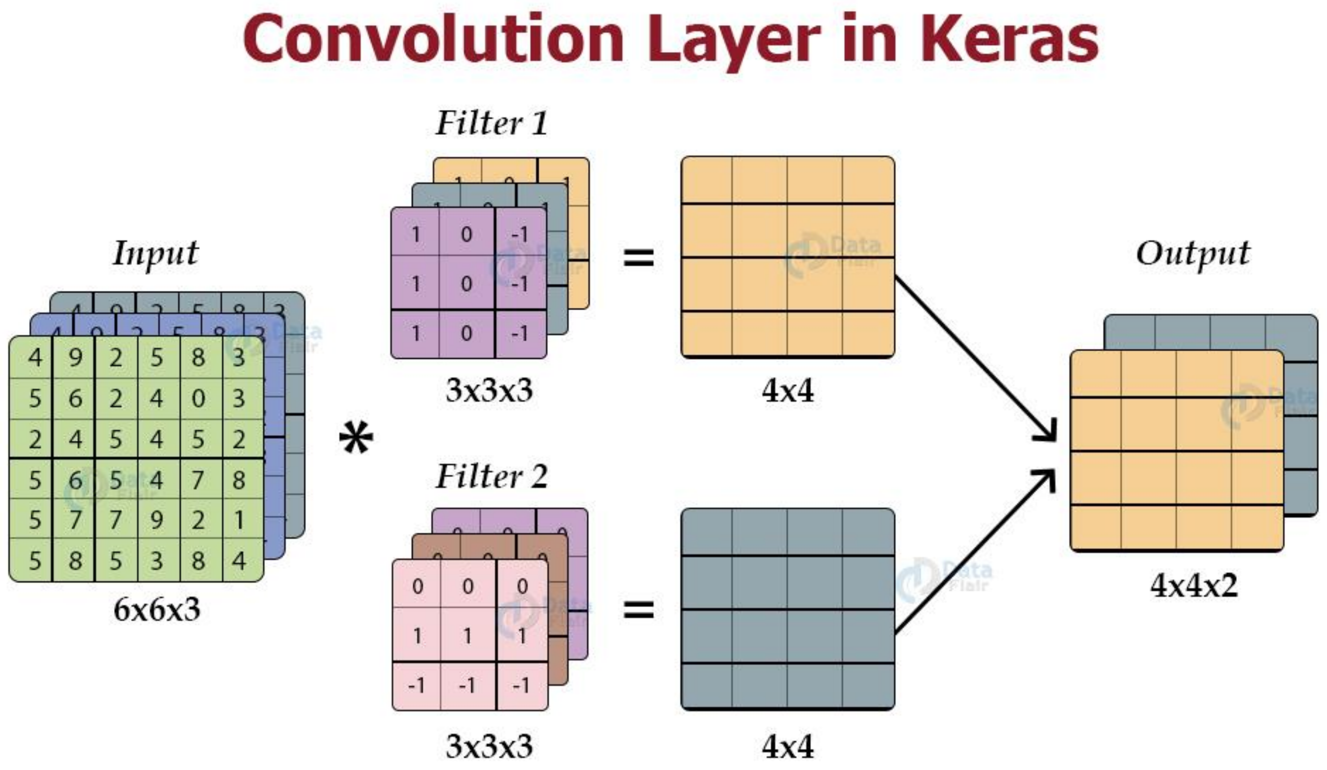


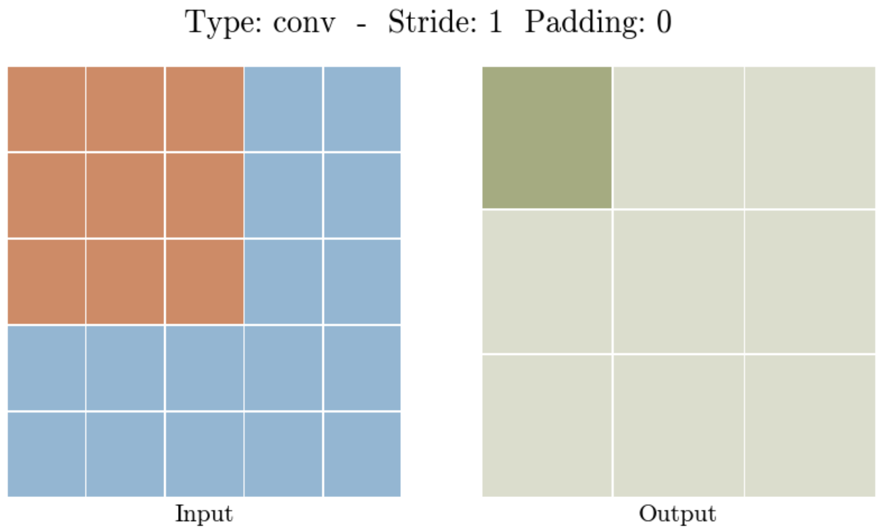
Figure courtesy of Thushan Ganegedara

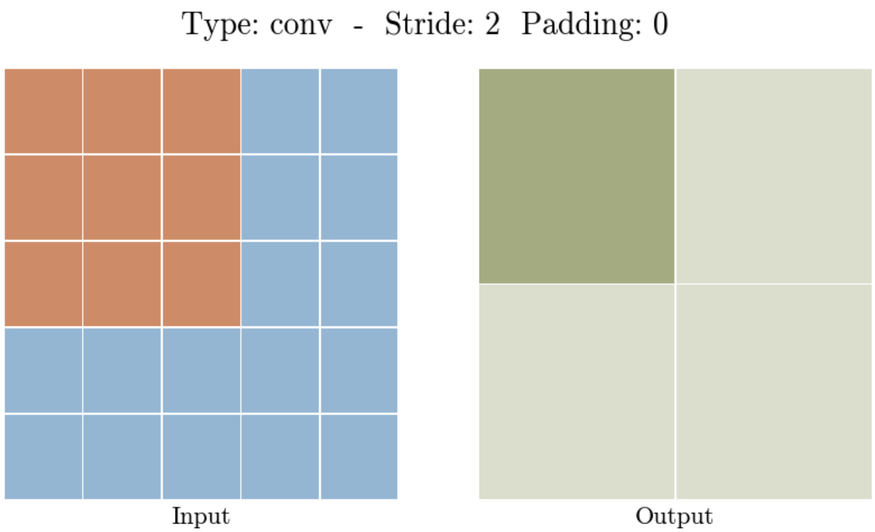
Mathematically Speaking…

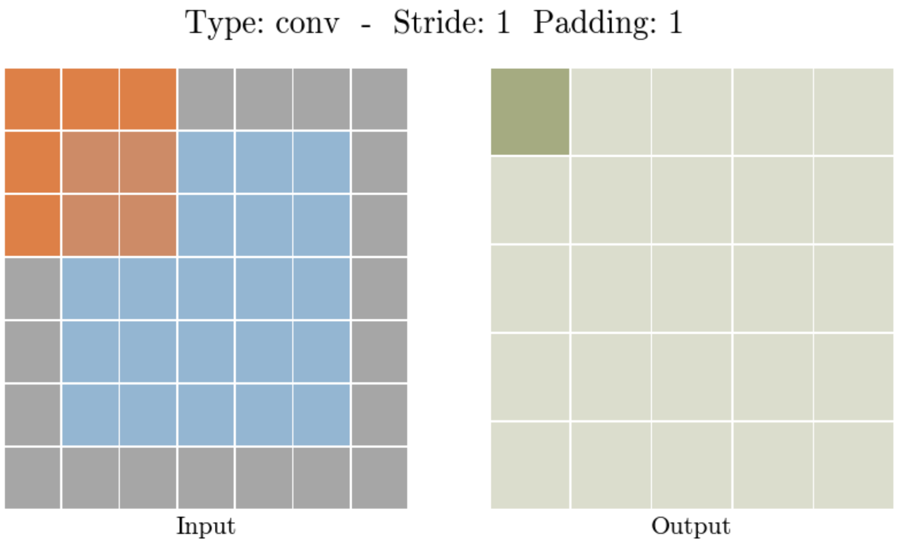


Stride and Padding

- Stride controls feature field overlap.
- Padding controls the down-sampling.



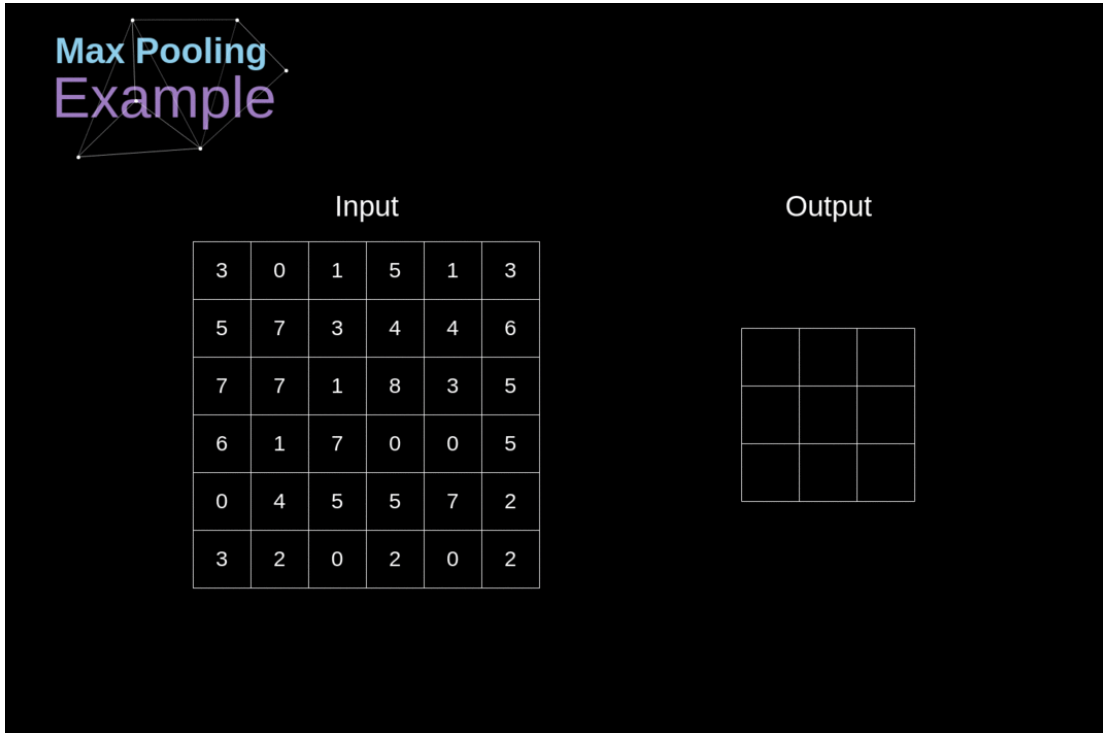




Aqeel Anwar

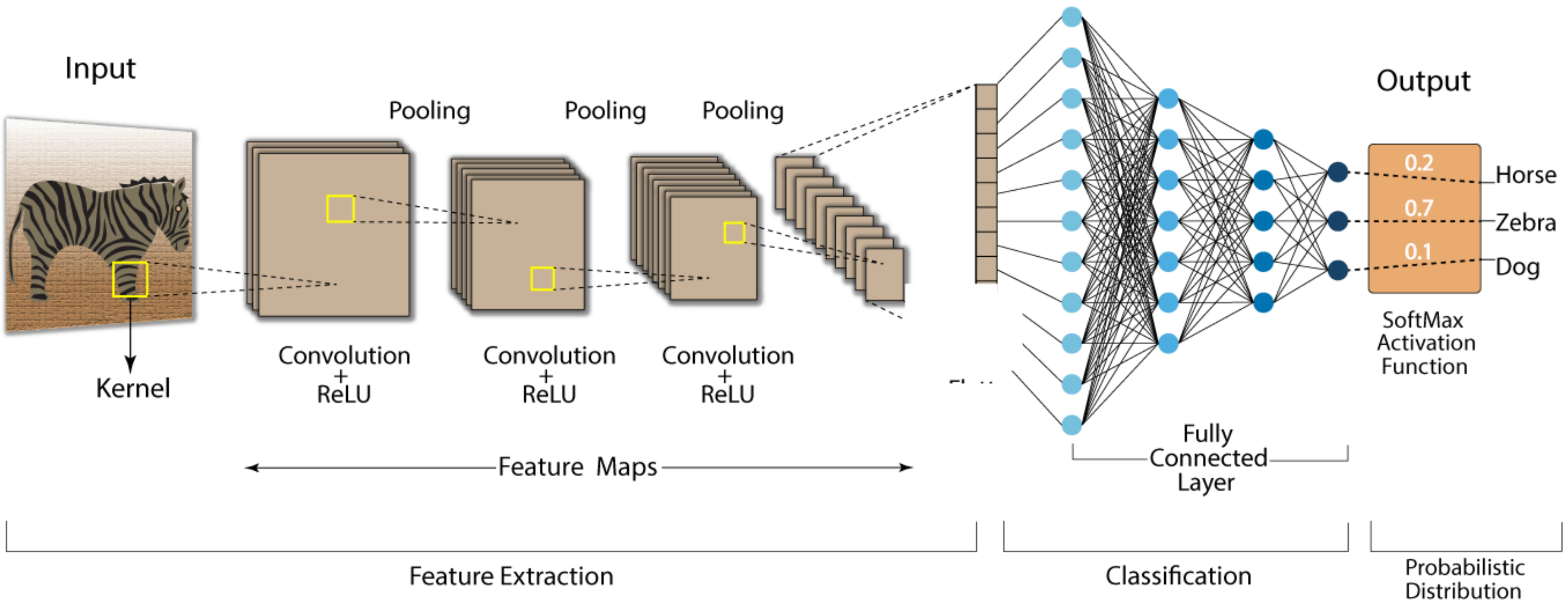
Non-Linearity: MaxPooling

- In addition to being a non-linearity…
  - it helps down-sample the image.
  - It helps summarize information in terms of larger blocks.



Putting It All Together

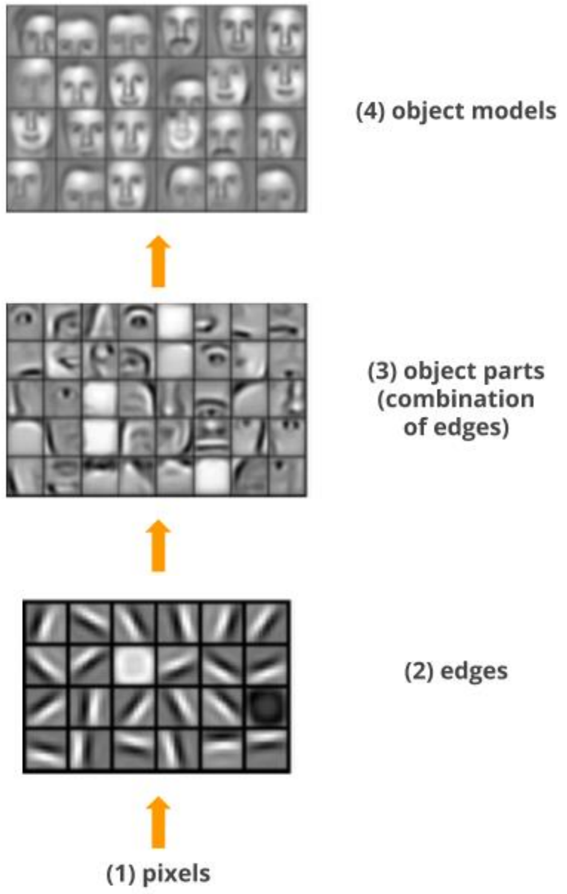
- Deeper layers generally have more kernels that are smaller.



Afaque Umer

Learned Features

- Early layers learn low-level features.
  - spots, edges, etc.
- Later layers learn to detect high-level features as a combination of low-level features.
  - Eyes, ears, hair, etc.
- Interpretability is not guaranteed (But there is great research interest…)
- Demo



https://micro-dimensions.com

Hyper-Parameters

Continued…

Batch Normalization

- Even if input data is properly normalized, the gradient in subsequent layers may vanish or explode.
- For that, you may add *"batch normalization"* at every layer.

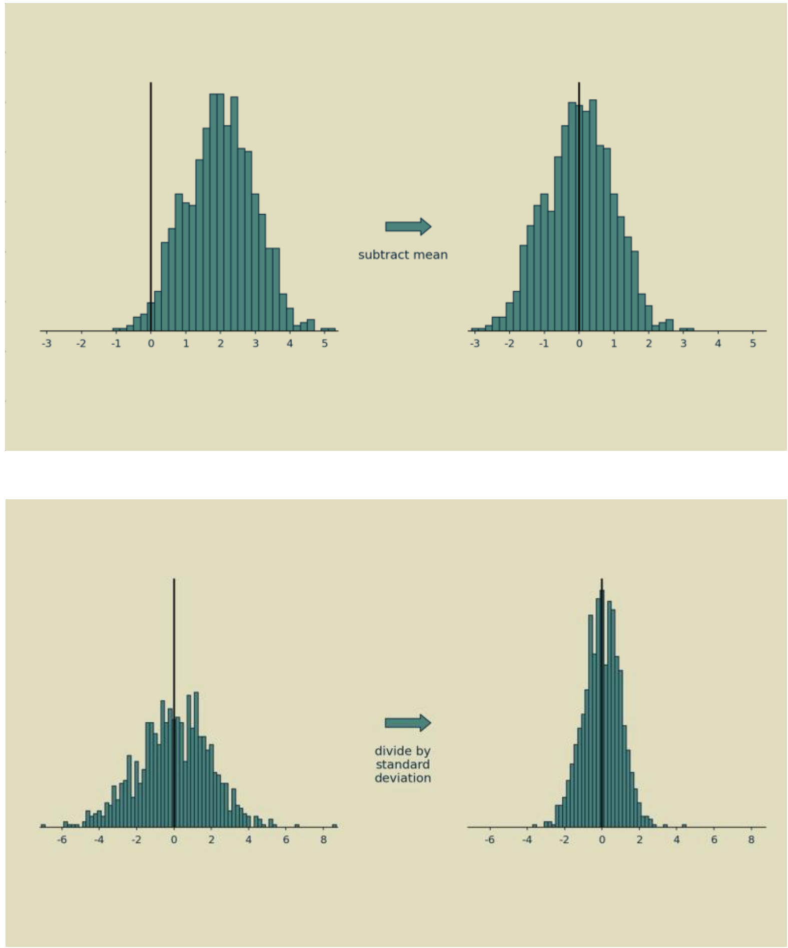


Figure courtesy of Brandon Rohrer

Learning Rate: Schedulers

- Since larger learning rates may converge faster but smaller ones are more stable, you could adjust the learning rate in phases to get the best of both worlds!
    - This way, you still converge but faster.

- Using a scheduler is a common practice.

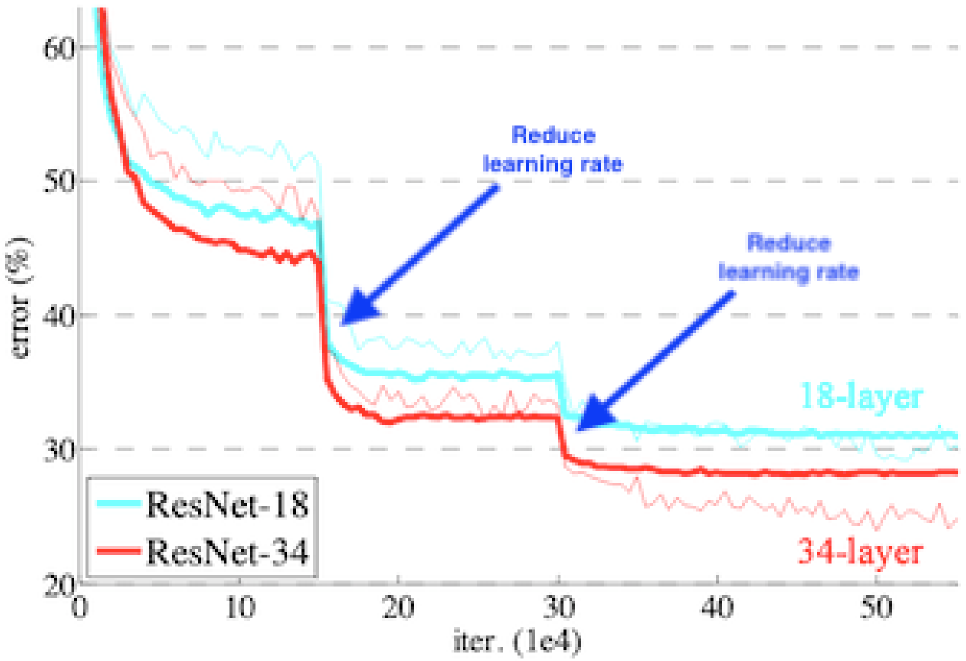


Figure courtesy of B. D. Hammel

Hyper-Parameter Tuning

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Be Smart About It

- It is expensive!
  - 1 hyper-parameter with 3 values → 3 experiments
  - 2 hyper-parameter with 3 values each → 9 experiments
  - 3 hyper-parameter with 3 values each → 27 experiments
  - … exponential growth!

Be Smart About It

- It is expensive!
- Start with generally accepted wisdom:
  - Start with good initial guesses.
  - Different settings work better for different models/problems (e.g., SGD + momentum for computer vision vs. Adam otherwise)
- Be picky about what to fine-tune.
  - Use early stopping.
  - Learning rate is the most important parameter!

Hyper-Parameter Tuning Methods

- Generally, use log-scale for numerical hyper-parameters.
- Random and Adaptive searches generally find optimal values faster than grid searches.

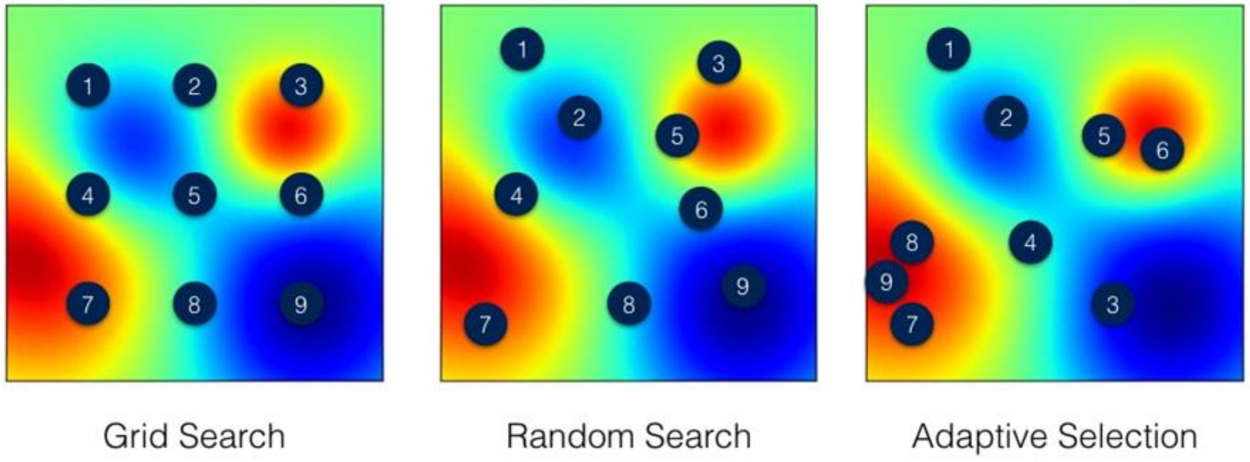


Figure courtesy of Liam Li

Advanced Techniques

Transfer Learning

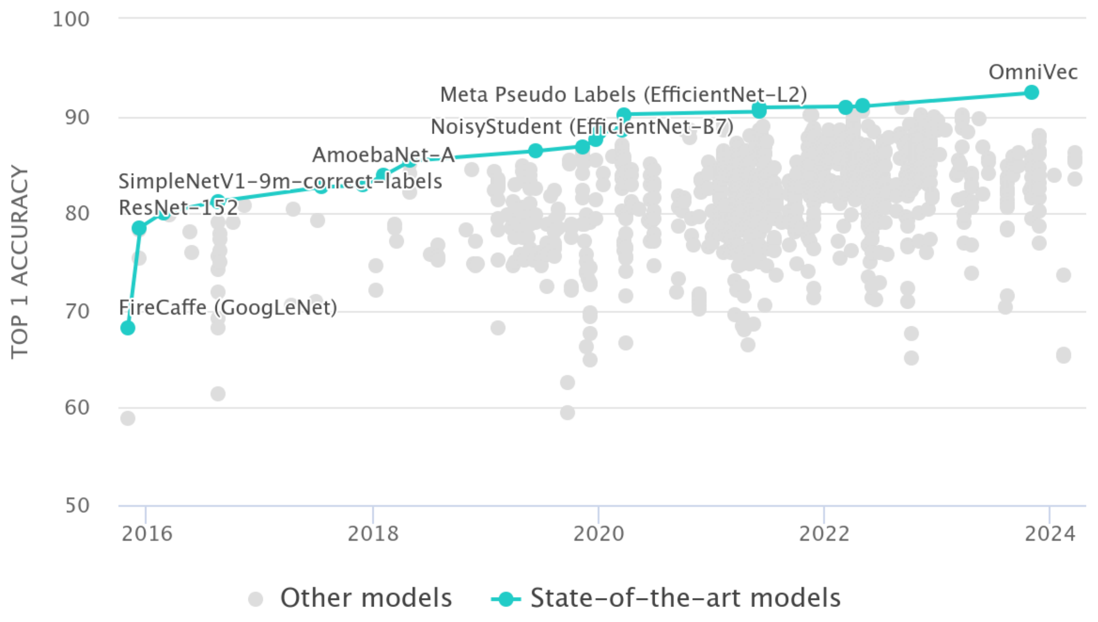
- Deeper networks have highly irregular loss surfaces. They are hard to train:
  1. They need relatively large amounts of data.
  2. They need relatively much compute resources to train and tune hyper-parameters.
- We need to somehow start with *“an advantage”*.

Transfer Learning

- We need to somehow start with *“an advantage”*.
- Large tech companies and research institutes are more capable than individuals in terms of data and compute resources.
  - They can afford to train their models from scratch.
  - Can we capitalize on their <u>*pre-trained*</u> models?

Transfer Learning

- A pre-trained model would already have learned useful features for a target problem.
  - For example, we can start with a model (e.g., ResNet) that was pre-trained on a large dataset (e.g., ImageNet: ~1.4M images. 1000 classes. ~3*469x387 pixels).



Data Augmentation

- As mentioned earlier, lack of large amounts of data is a problem.
  - Model may overfit (learn “spurious” features).
  - Model may not generalize well to “out-of-distribution” data.

Data Augmentation

- What is a lion exactly?
- To increase the amount of data and add make sure the learned features are diverse…
  - introduce as much valid variations as possible to the dataset.