Introduction to Deep Learning with GPUs

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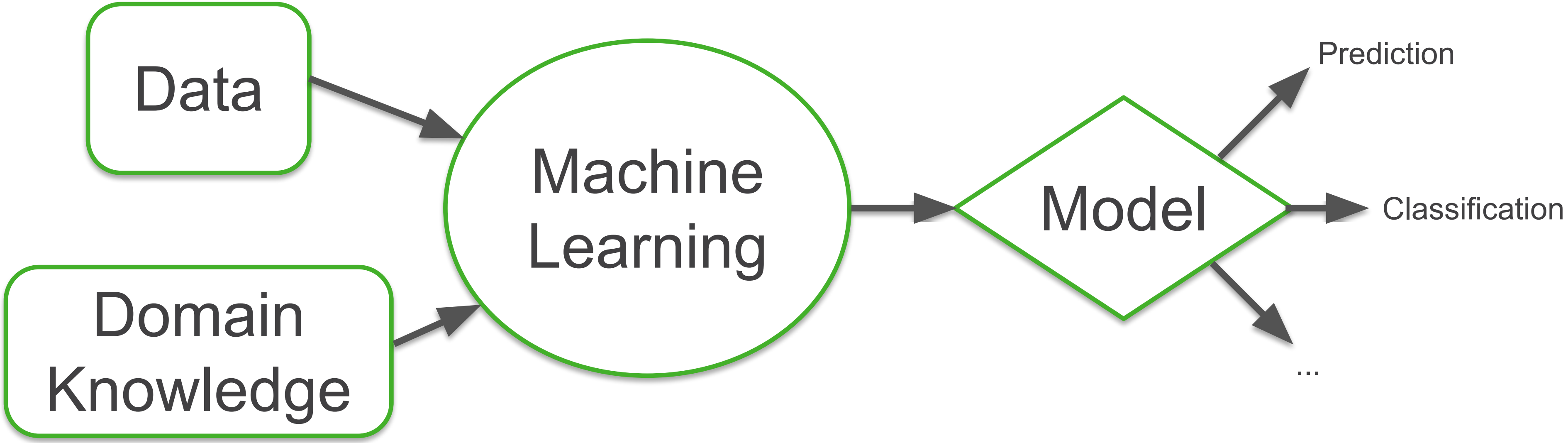
Part 1: Machine Learning Basics in Anaconda

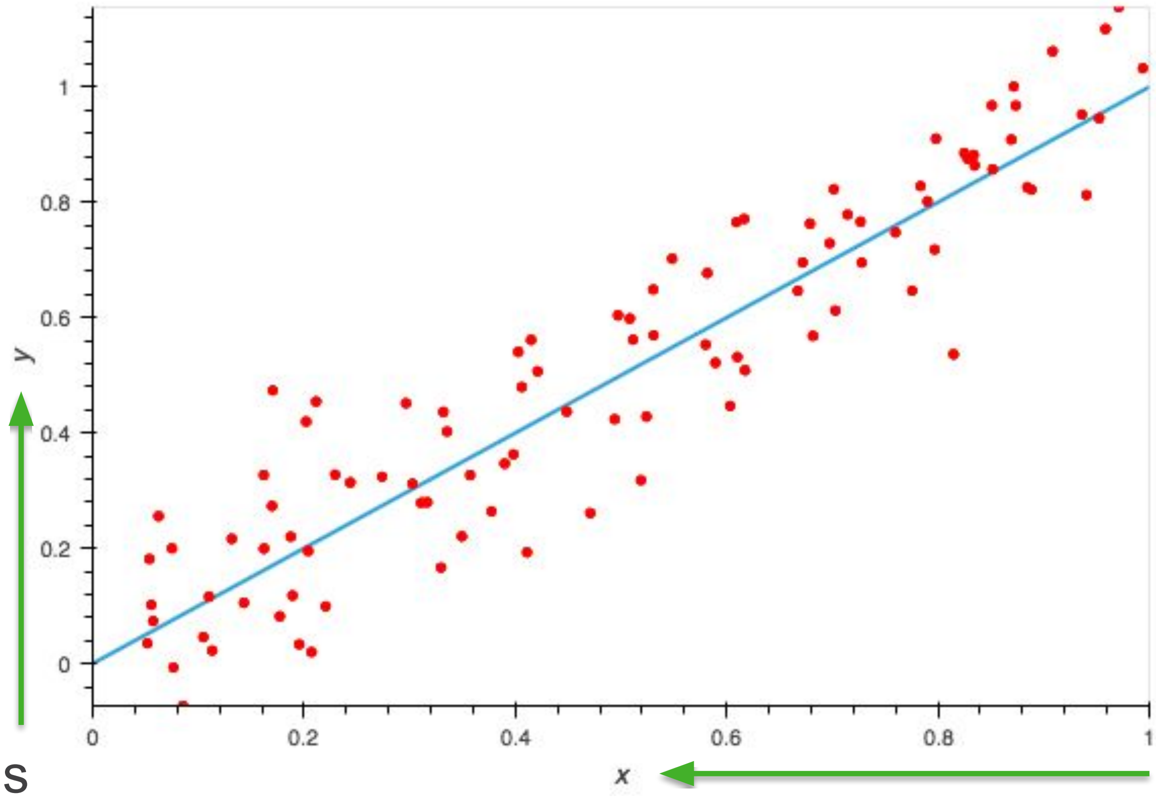
What is Machine Learning?



What can machine learning help us do?

- **Predict the future:**
  - ✓ *"How much corn will I sell next month?"*
- **Reveal hidden information:**
  - ✓ *"How many truck tires likely fail to meet our durability specification based on the temperature data collected during their manufacture?"*
- **Identify structure in large data sets:**
  - ✓ *"Can business loan applications be grouped by common attributes?"*
- **Find unusual trends:**
  - ✓ *"Which items in my grocery store have seen an abnormal sales decrease outside of historical seasonal variation?"*

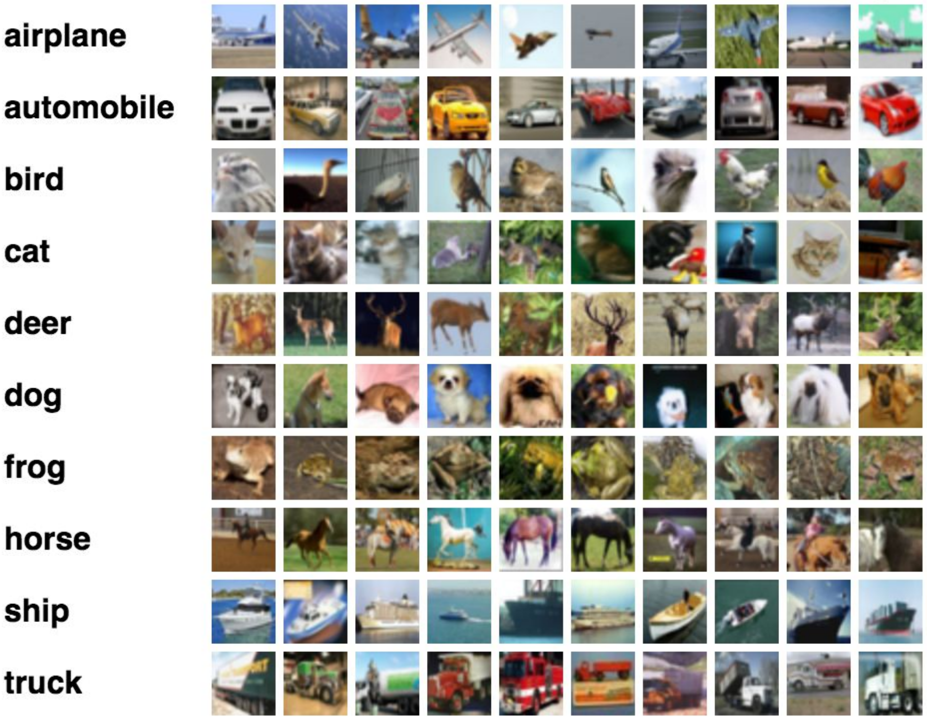
ML Categories: Regression



predict this

observe this

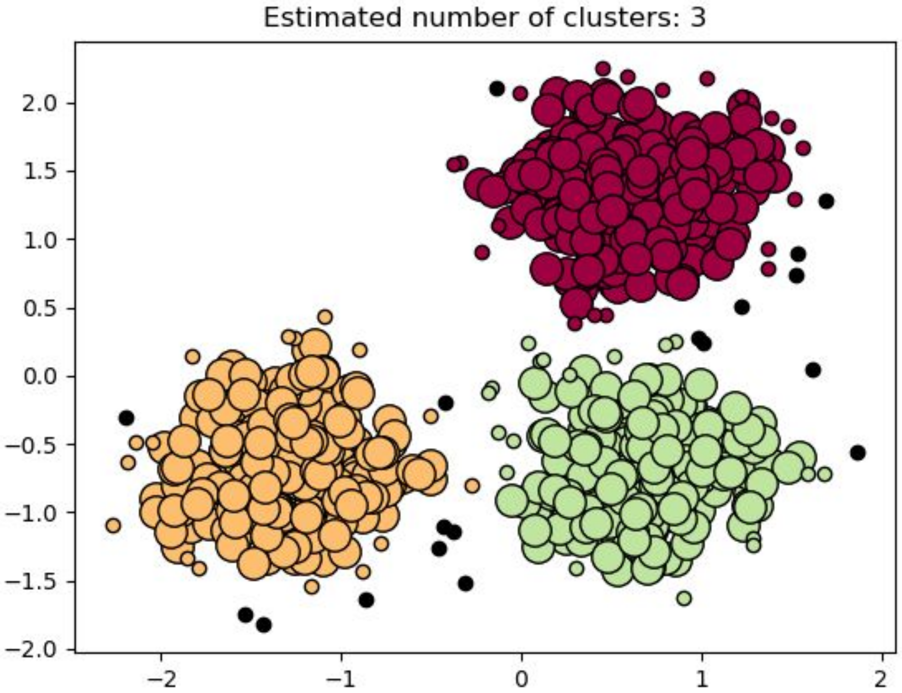
ML Categories: Classification



- Assign each sample to one or more categories.
- Categories known ahead of time
- Can be **exclusive** or **inclusive**

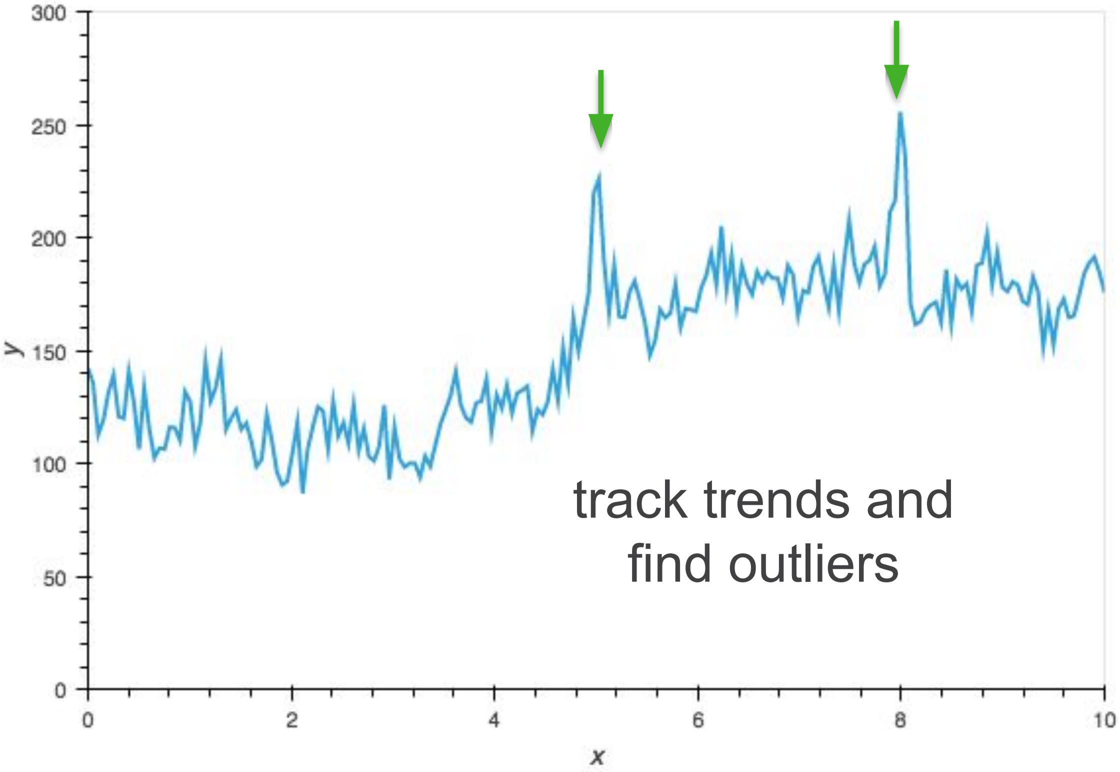
ML Categories: Clustering

- Divide a set of items into groups
- Categories are **not** known ahead of time



http://scikit-learn.org/stable/auto_examples/cluster/plot_dbscan.html

ML Categories: Anomaly Detection



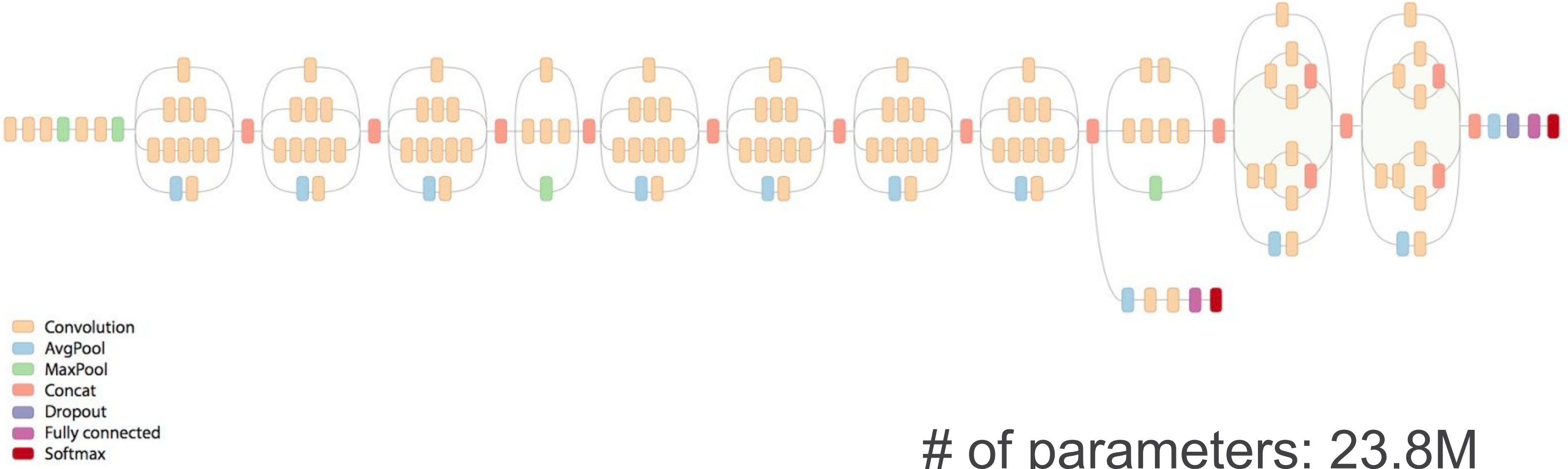
track trends and find outliers

ML Categories: Generation

http://genekogan.com/works/style-transfer/

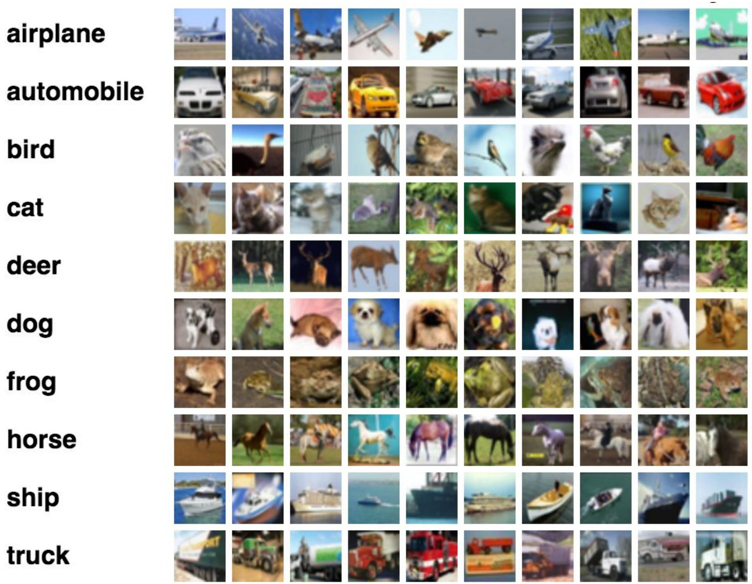
Deep Learning

Inception v3 Network



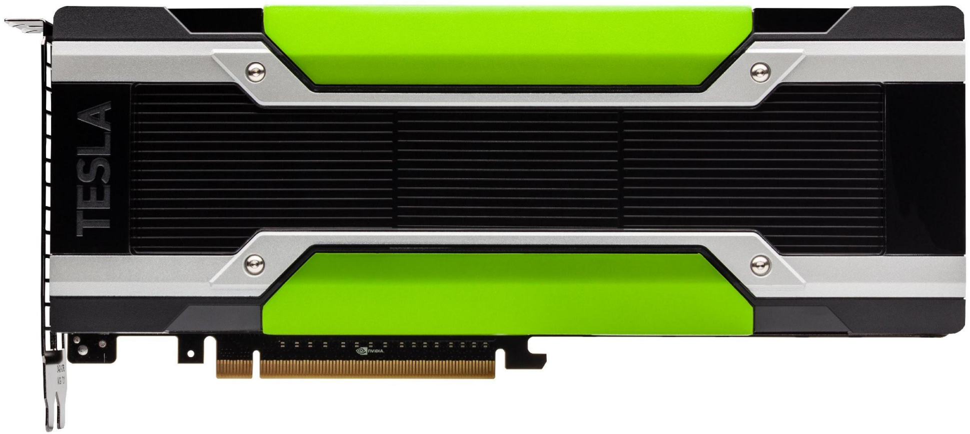
# of parameters: 23.8M
# of layers: ~140

Today's (Toy) Problem



- **Can we classify small color images into one of 10 categories?**
- Goal is better than 75% accuracy
- We will build a deep learning model and train it with GPUs.

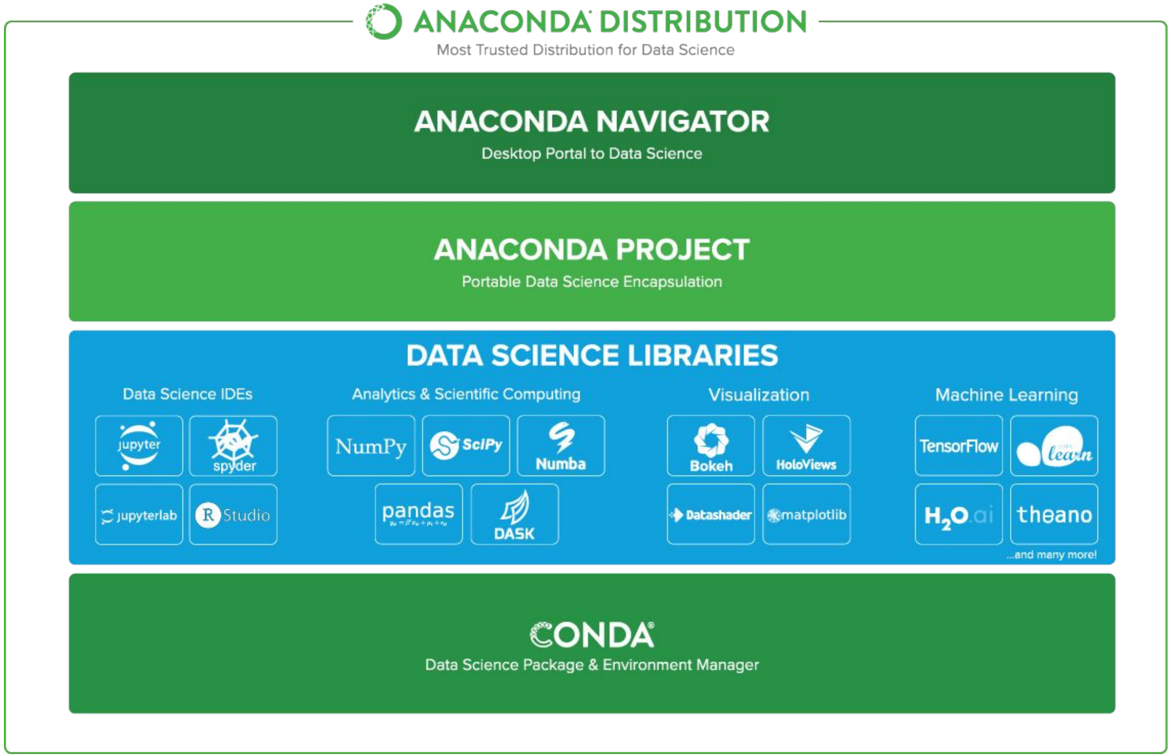
Hardware: NVIDIA GPUs



Tesla P100
3584 CUDA cores
9.3 TFLOPS (single precision)
16 GB Memory
732 GB/sec

× 56

Software: Anaconda Individual Edition



Already installed in your tutorial environment

ANACONDA CON 2020

GPU-Accelerated Packages in Anaconda

TensorFlow

Keras

PYTORCH

Caffe

Chainer

CuPy

Numba

mxnet

dmlc XGBoost

GPU-Accelerated Packages in Anaconda

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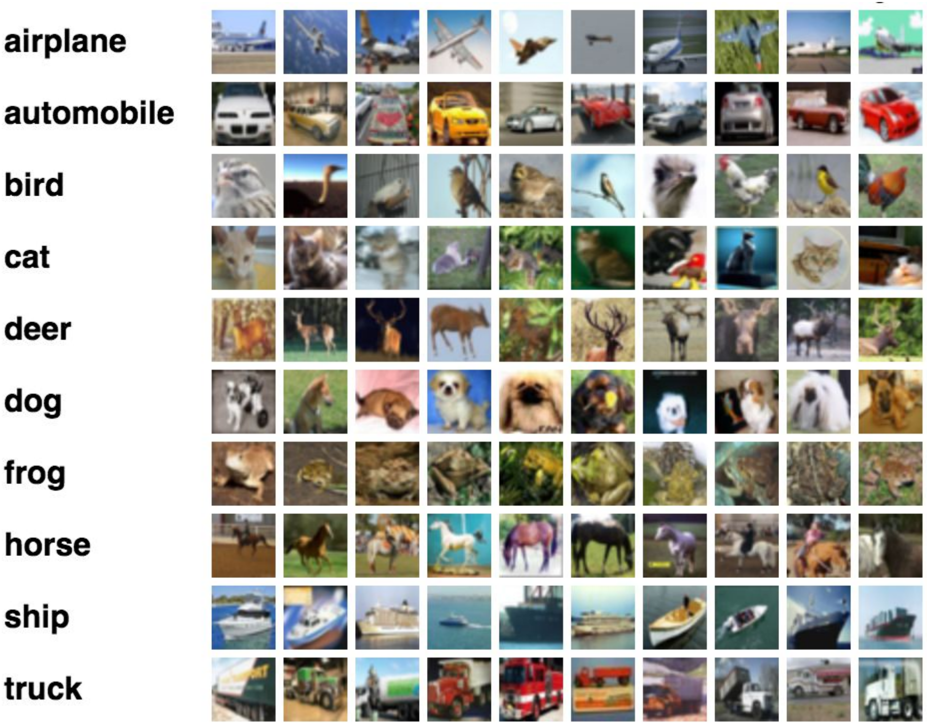
Data: CIFAR10 Image Set

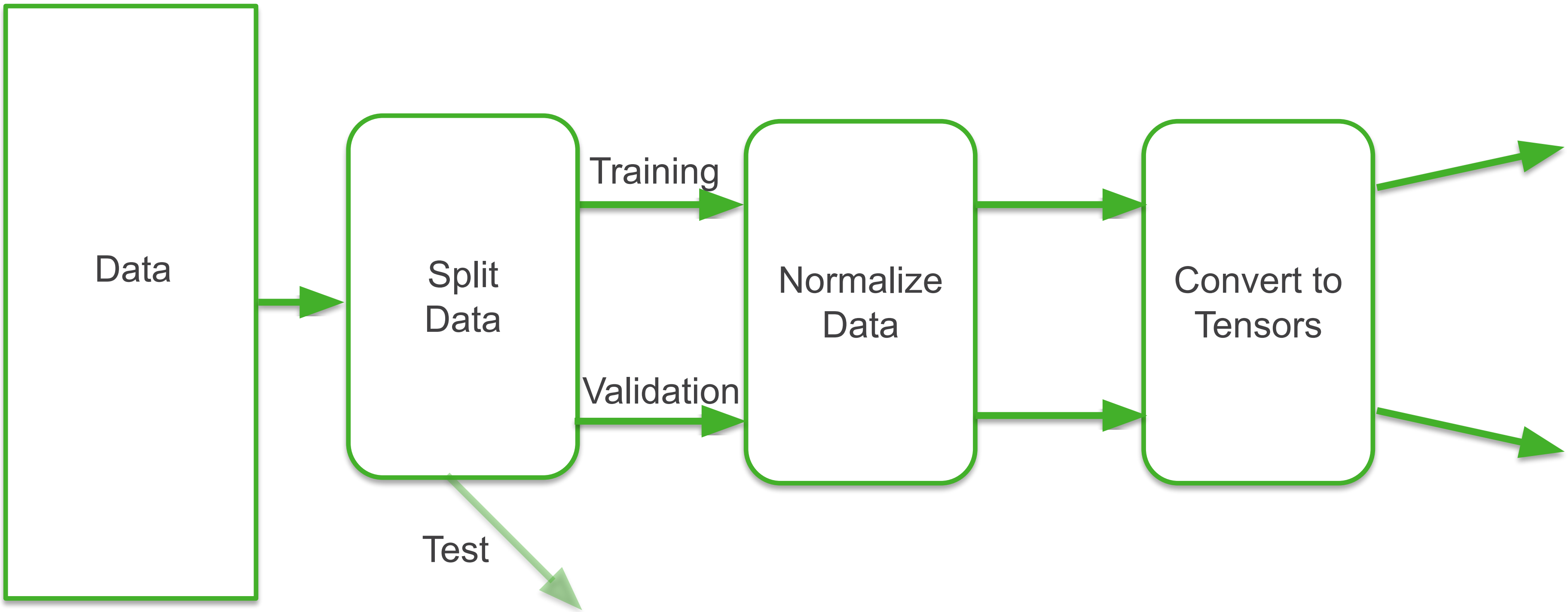


https://www.cs.toronto.edu/~kriz/cifar.html

Classic data set for benchmarking image classification

- 60,000 images
- 32x32 color pixels
- 10 classes
- 6000 images from each class
- Classes are mutually exclusive

Data Preparation Process



One-Hot Encoding of Category Variables

Category #
1
0
2
3
3
1
2

0	*1*	*2*	*3*
0	**1**	0	0
1	0	0	0
0	0	**1**	0
0	0	0	**1**
0	0	0	**1**
0	**1**	0	0
0	0	**1**	0

Exercise 1: Data Exploration and Prep

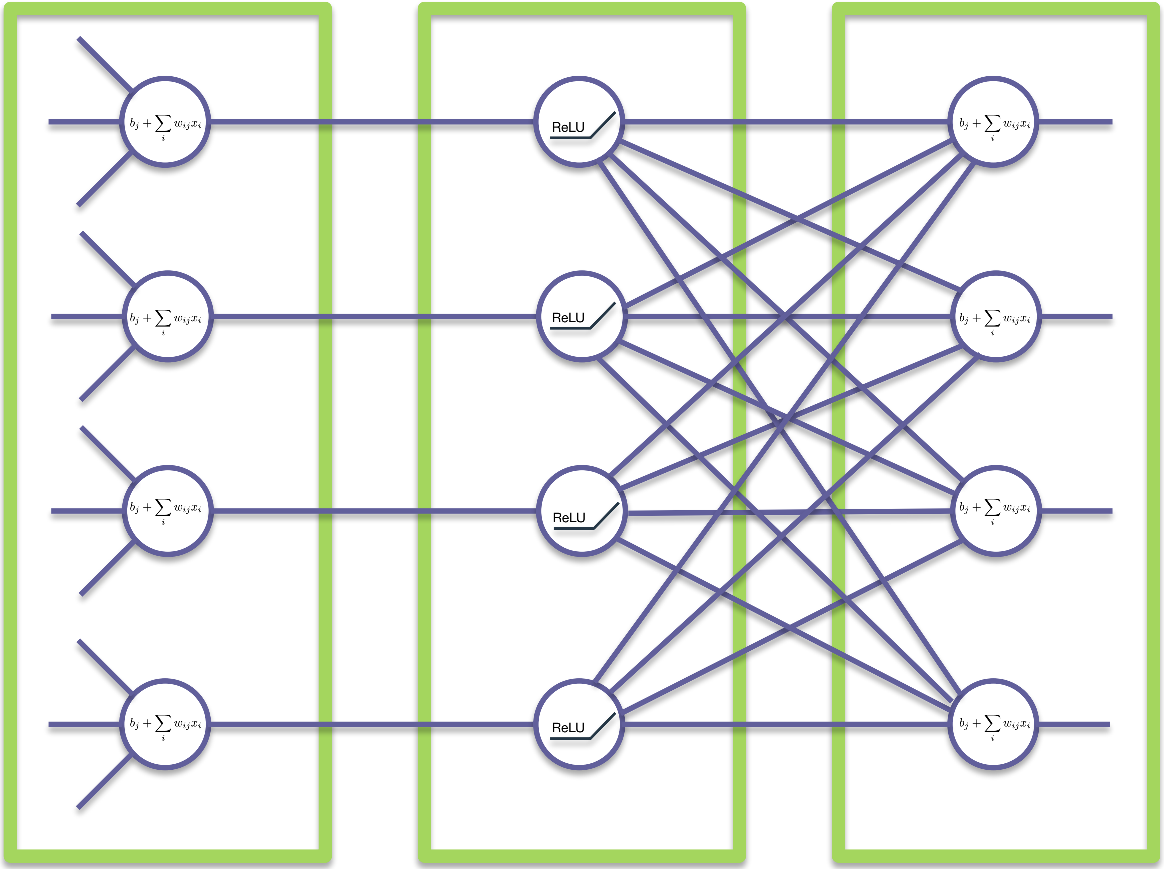
Part 2: Introduction to Deep Learning with Keras

What is a neural network?

- *A "biologically-inspired" method for making models out of simple computational units connected to form a large mesh*
- Very flexible.
- Require a lot of data to train.
- Although described in physical terms (nodes, layers, etc), they are always implemented in software using array math.
- **No relation to neuroscience, artificial general intelligence, or other sci-fi stuff.**

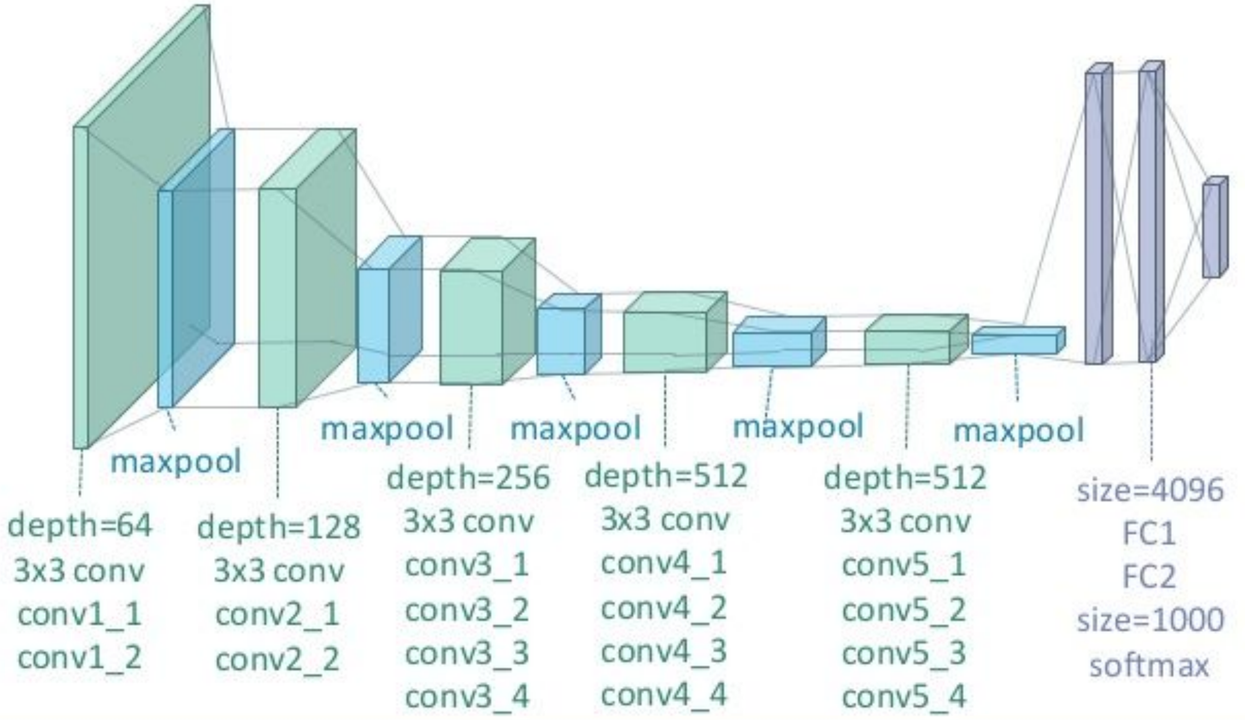
https://www.flickr.com/photos/usdagov/16802162424

Network


$b_j + \sum_i w_{ij}x_i$
$b_j + \sum_i w_{ij}x_i$
$b_j + \sum_i w_{ij}x_i$
$b_j + \sum_i w_{ij}x_i$
ReLU
ReLU
ReLU
ReLU
$b_j + \sum_i w_{ij}x_i$
$b_j + \sum_i w_{ij}x_i$
$b_j + \sum_i w_{ij}x_i$
$b_j + \sum_i w_{ij}x_i$

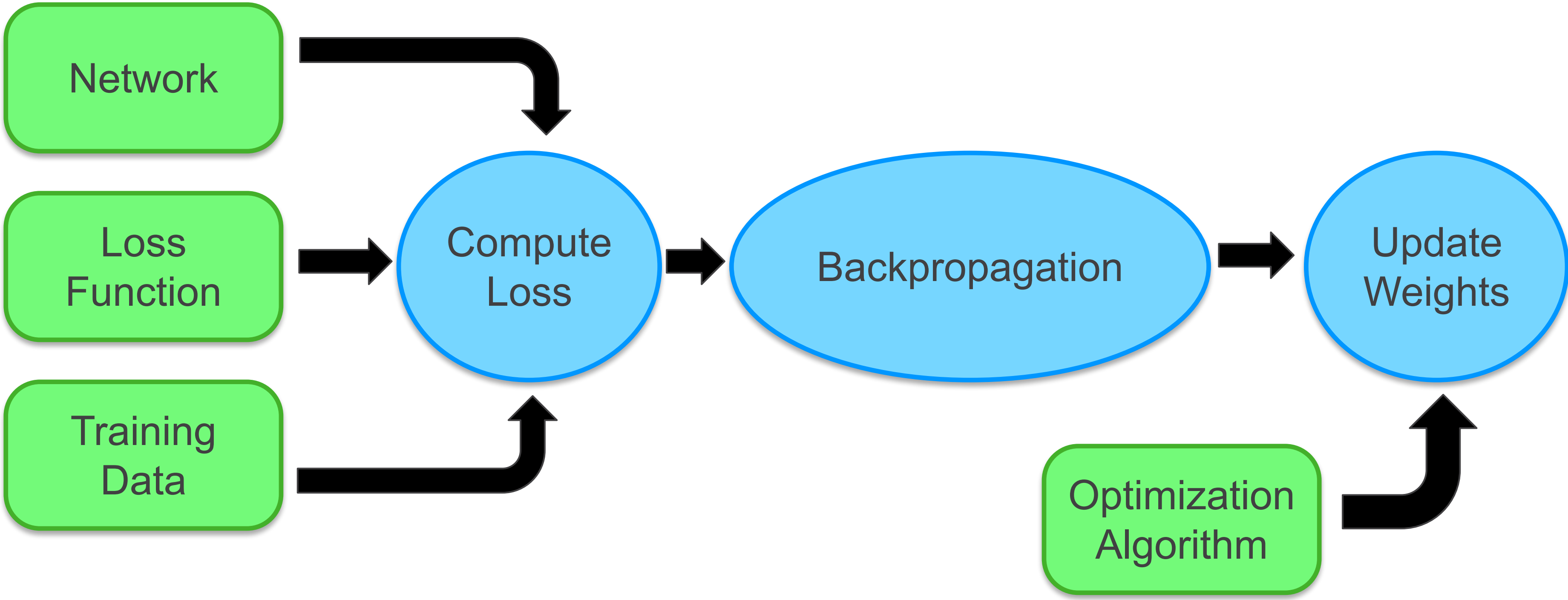
An Image Classification Network

VGG19



https://www.slideshare.net/ckmarkohchang/applied-deep-learning-1103-convolutional-neural-networks

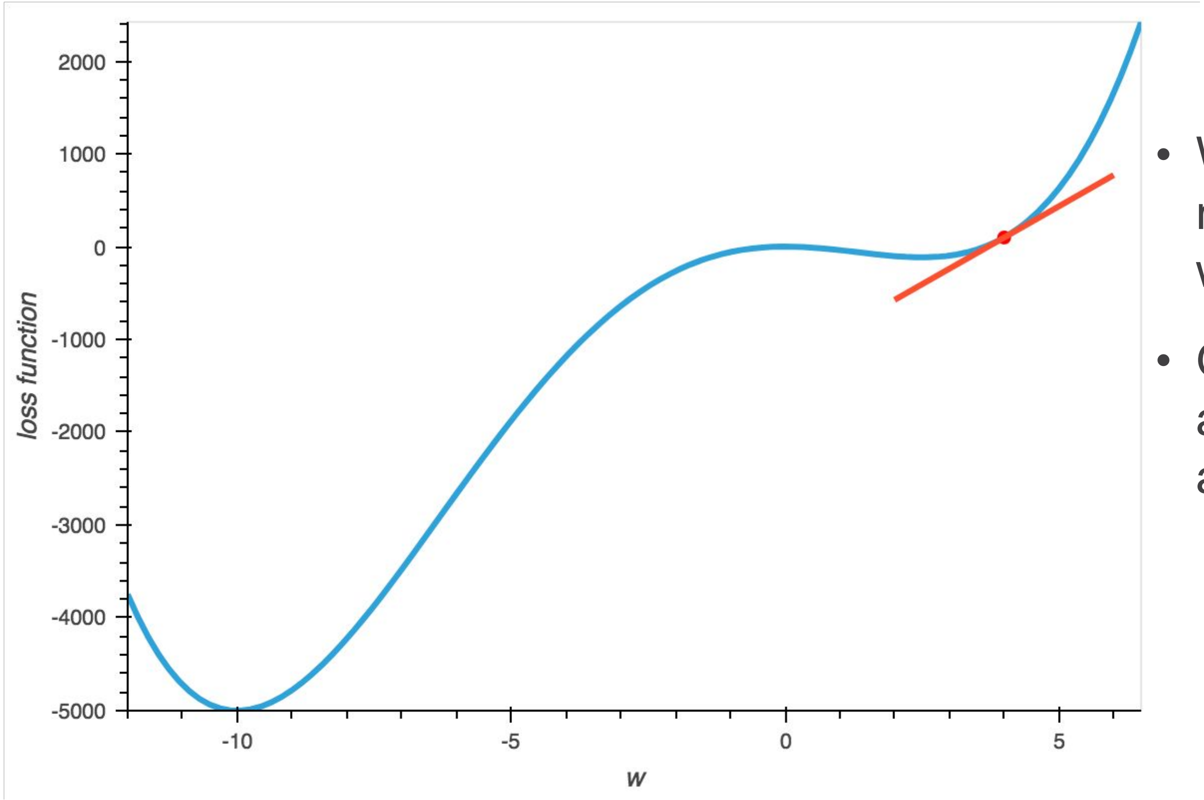
Training a Network



Loss Functions

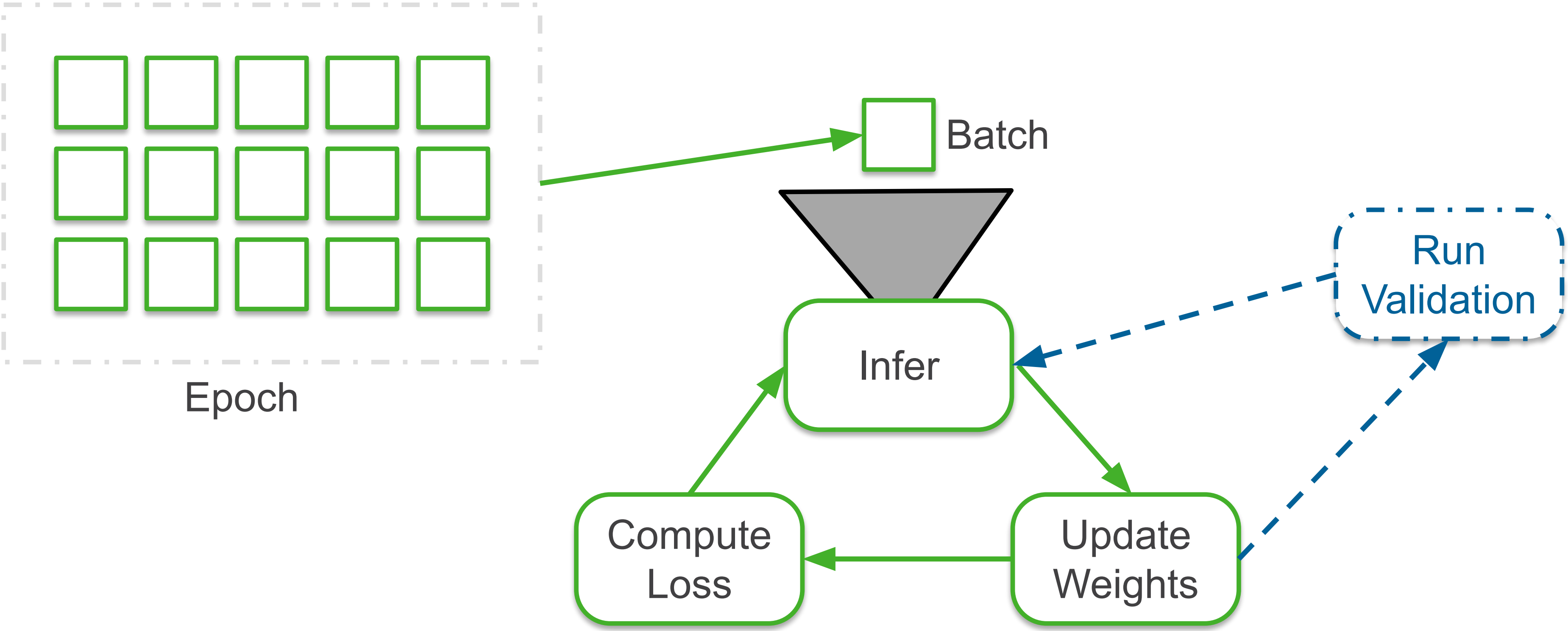
- The optimizer will try to minimize the loss function on the training data
- *Picking a loss function depends on the kind of model you are building*
- Some good default choices:
  - Regression: **mean_squared_error**
  - Binary classification: **binary_crossentropy**
  - Multi-category classification: **categorical_crossentropy**

Backpropagation & Optimization



- Work backwards through network to compute each weight affects loss function
- Optimization algorithm adjusts each weight according to some strategy.

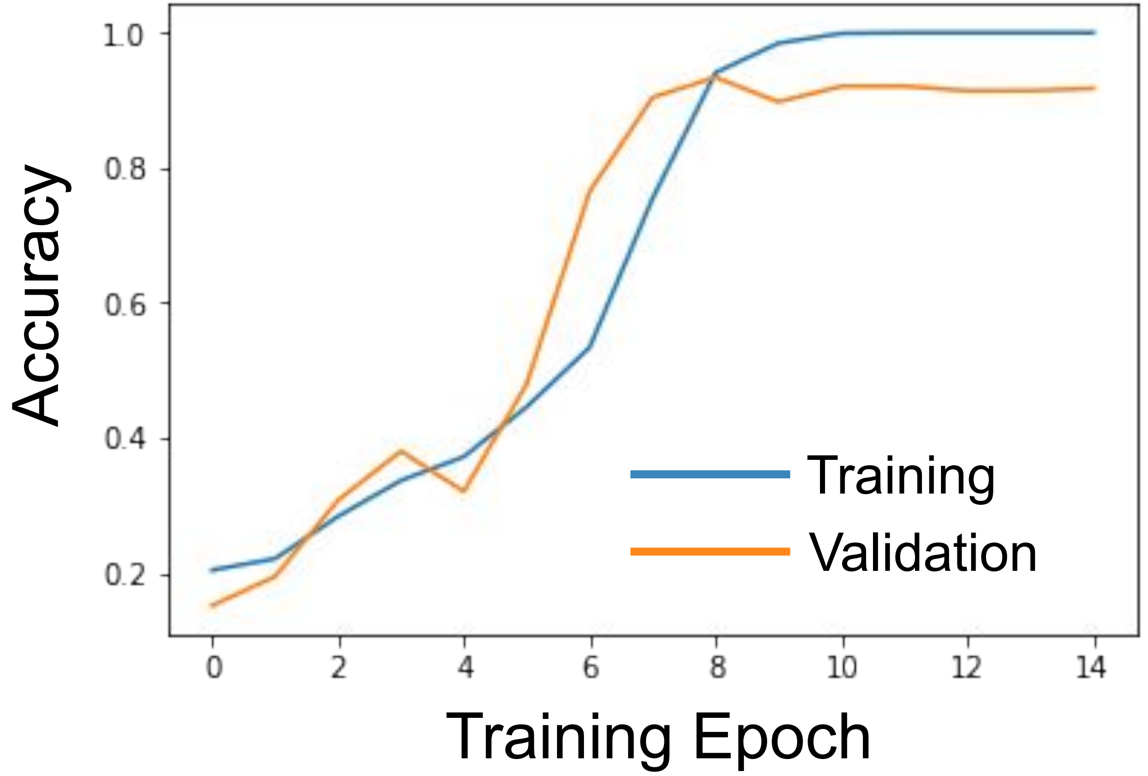
Batches and Epochs



Exercise 2: Building and Training Models

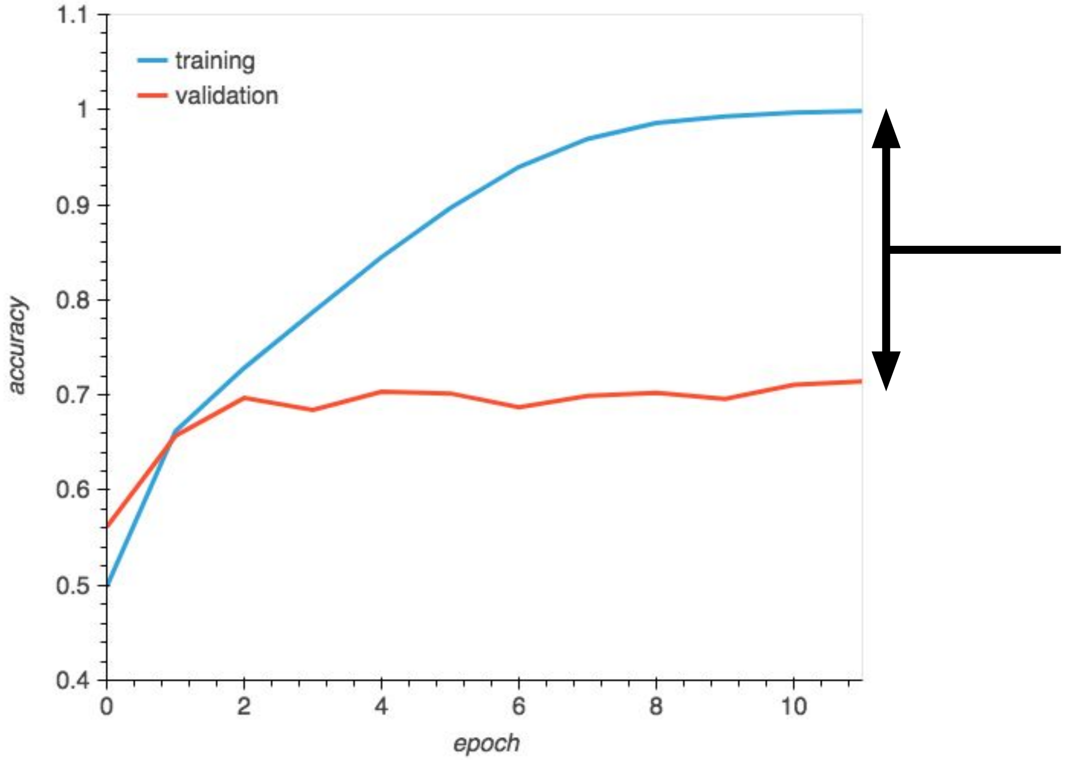
Part 3: Evaluating Models

Most important question in ML



How do I know when I am done?

Overfitting



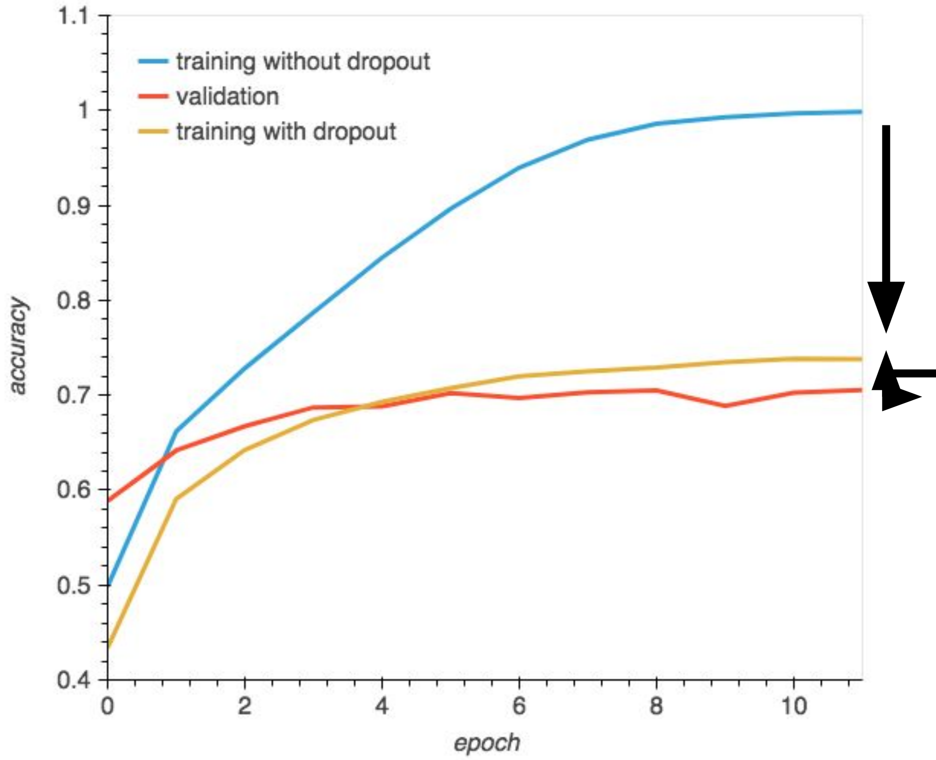
Gap caused by model overfitting

What to do about overfitting?

- **Overfitting does not mean your model is bad.**
  - Most models will overfit after enough training epochs
  - *The validation data accuracy is what you care about*

- Techniques exist to control overfitting:
  - Regularization
  - Dropout layers
  - Reduce size of network
  - Get more data

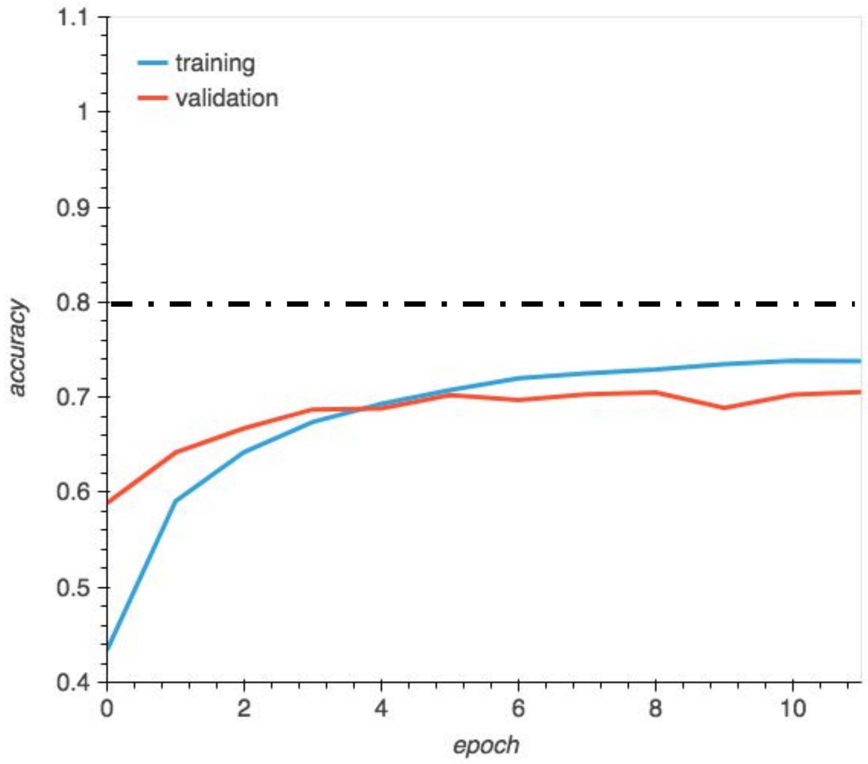
After Adding Dropout



Much less overfitting

But now we have a new problem...

Underfitting

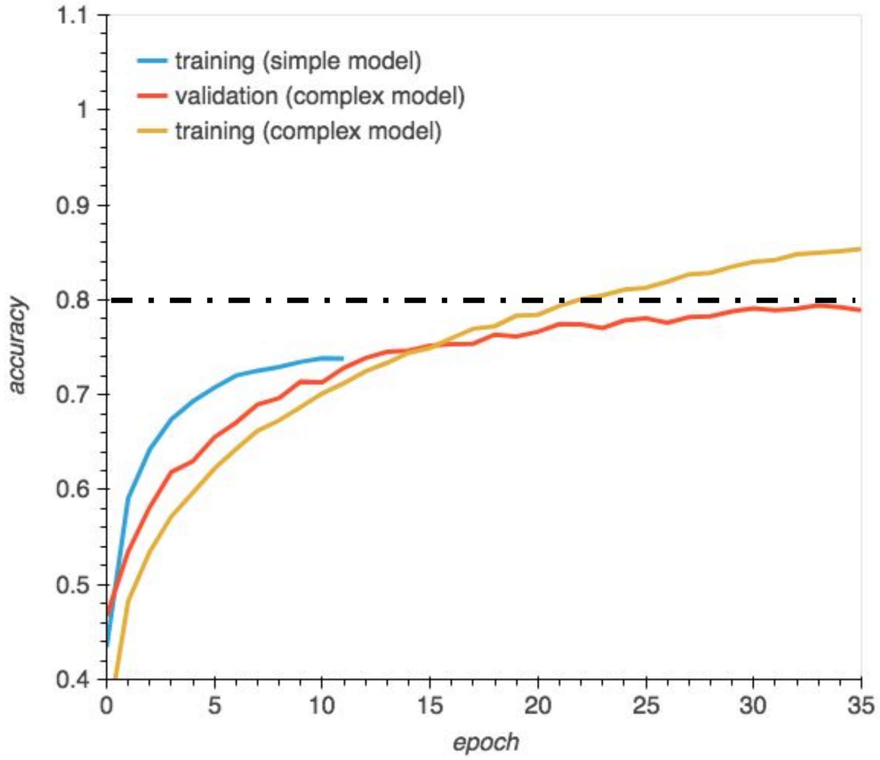


Model accuracy never reaches the goal.

Possible causes:

- Model too simple?
- Not enough training data?
- Mislabeled data?
- Optimizer learning rate?
- ...

Fixing Underfitting



Changed 2 things

- Increased model complexity (added extra convolutional layers)
- Changed optimizer algorithm

Trial and error is still the norm...

Limitations of Accuracy

- Accuracy is like the "check engine light"
- Can hide some problems
- ***Interpretation is hard if your training data is unbalanced***
- Important to look at other measures:
  - False positive rate
  - False negative rates
  - Confusion matrix
  - Inspect fail cases!

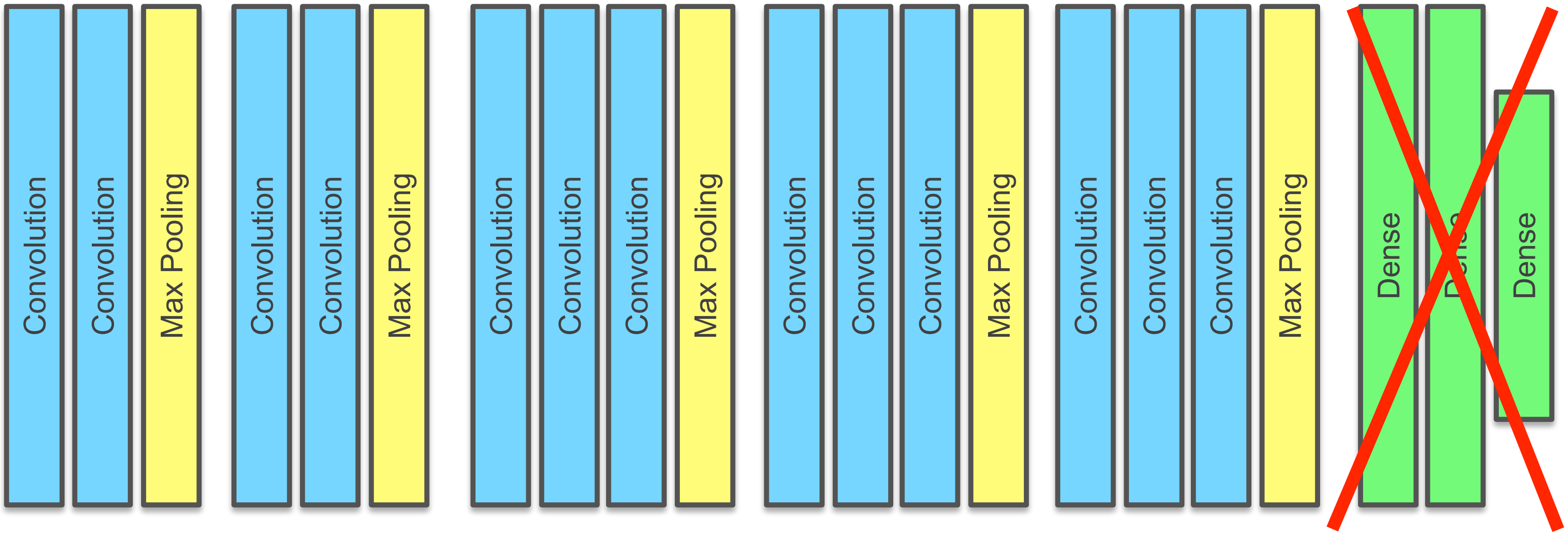
Part 4: Using Predefined Models and Deployment

Building on Existing Models

- In practice, you will generally use models defined by researchers, rather than construct new ones from scratch. Keras comes with quite a few:
  - VGG16
  - ResNet50
  - InceptionV3
  - MobileNet
  - NASNet
  - https://keras.io/applications/#documentation-for-individual-models

- Three approaches to retraining (slower to faster):
  1. Retrain existing architecture from scratch
  2. Retrain existing architecture starting from existing trained weights
  3. **Retrain only the final dense layers**

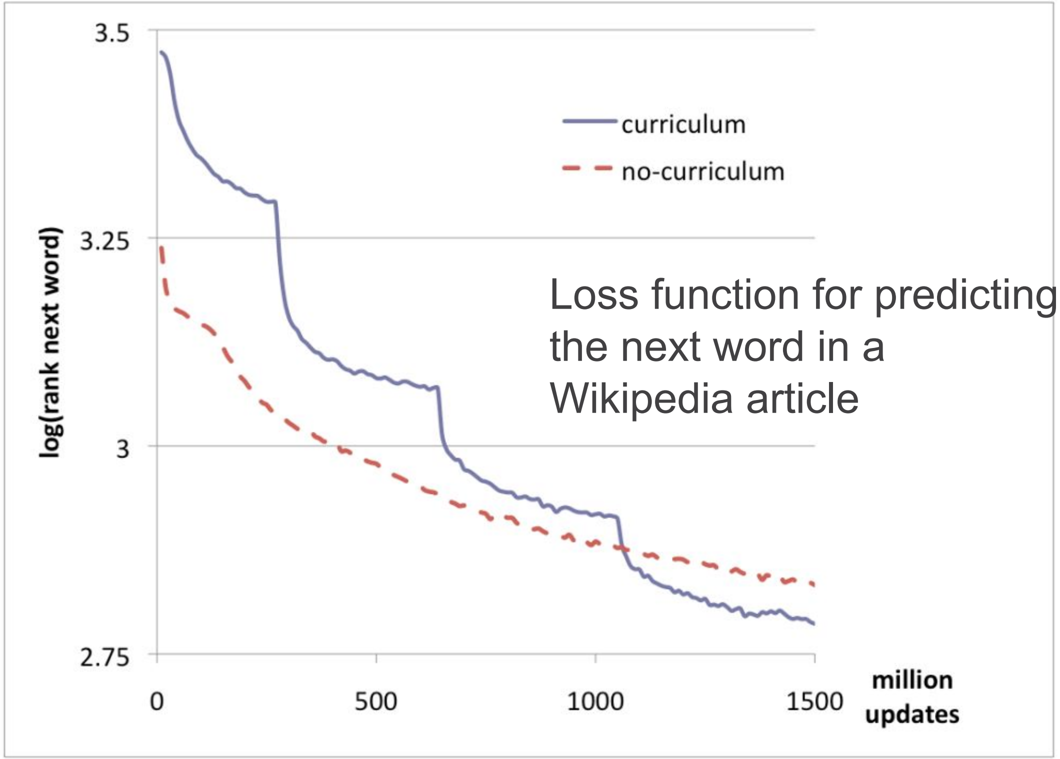
Transfer Learning



VGG16 Pretrained on ImageNet

Chop top layers off and retrain your own layers

Curriculum Learning

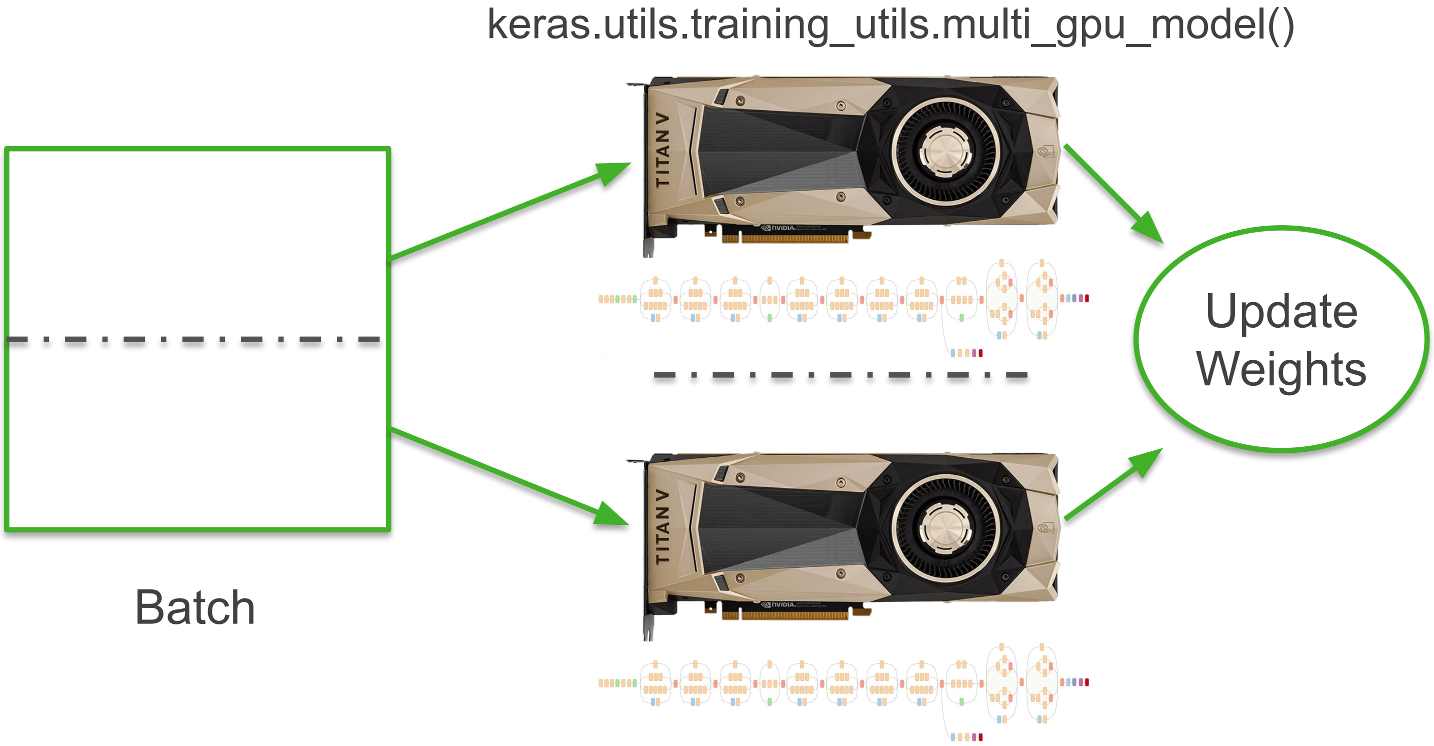


Loss function for predicting the next word in a Wikipedia article

- Train the model in multiple passes
- Use increasingly hard examples on each pass
- Easy if your data has a "difficulty" knob

Bengio, et al, ICML 2009

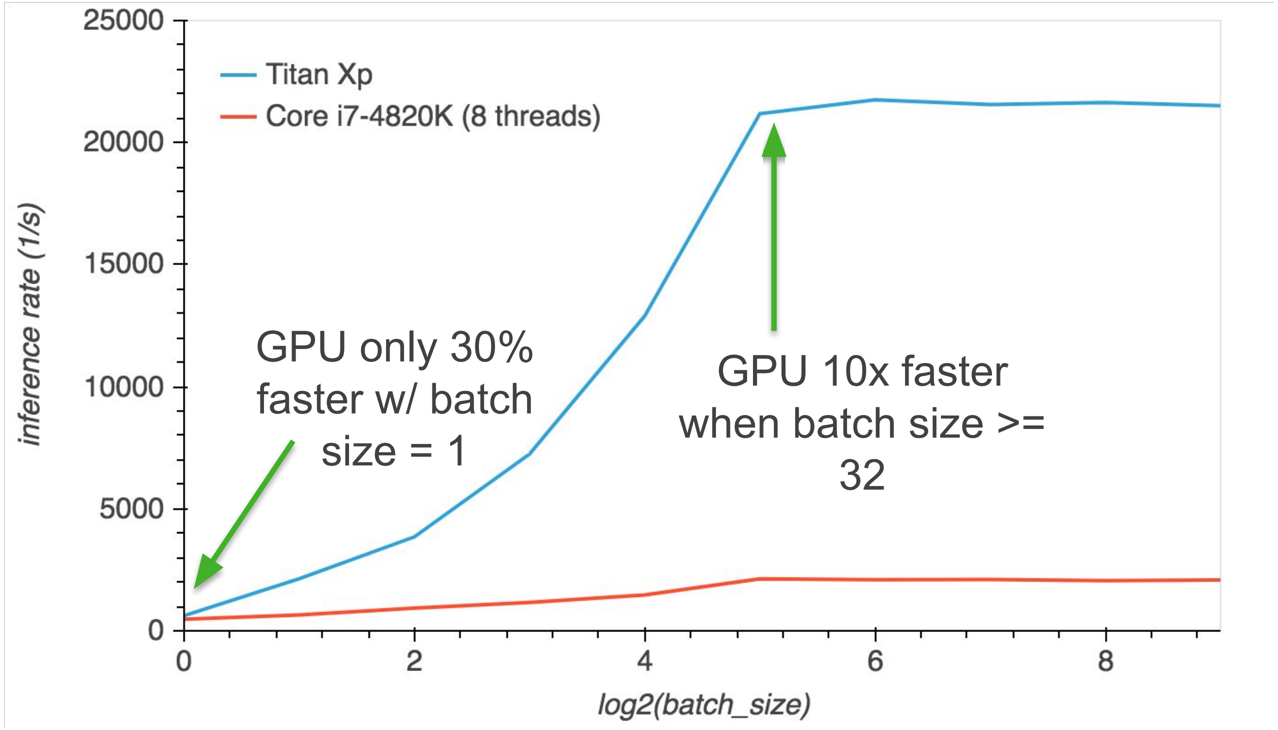
Using Multiple GPUs



Getting to Deployment

- **This was the point of doing all this, right?**
- Tools and best practices evolving rapidly
- Questions to consider:
    - What hardware is available in production?
    - Bulk processing or online processing? (or both?)
    - What is the performance requirement (throughput, latency)?
    - Does the model need optimization? (memory size or speed)
    - How should I package it, along with dependencies?

Determining Hardware Needs

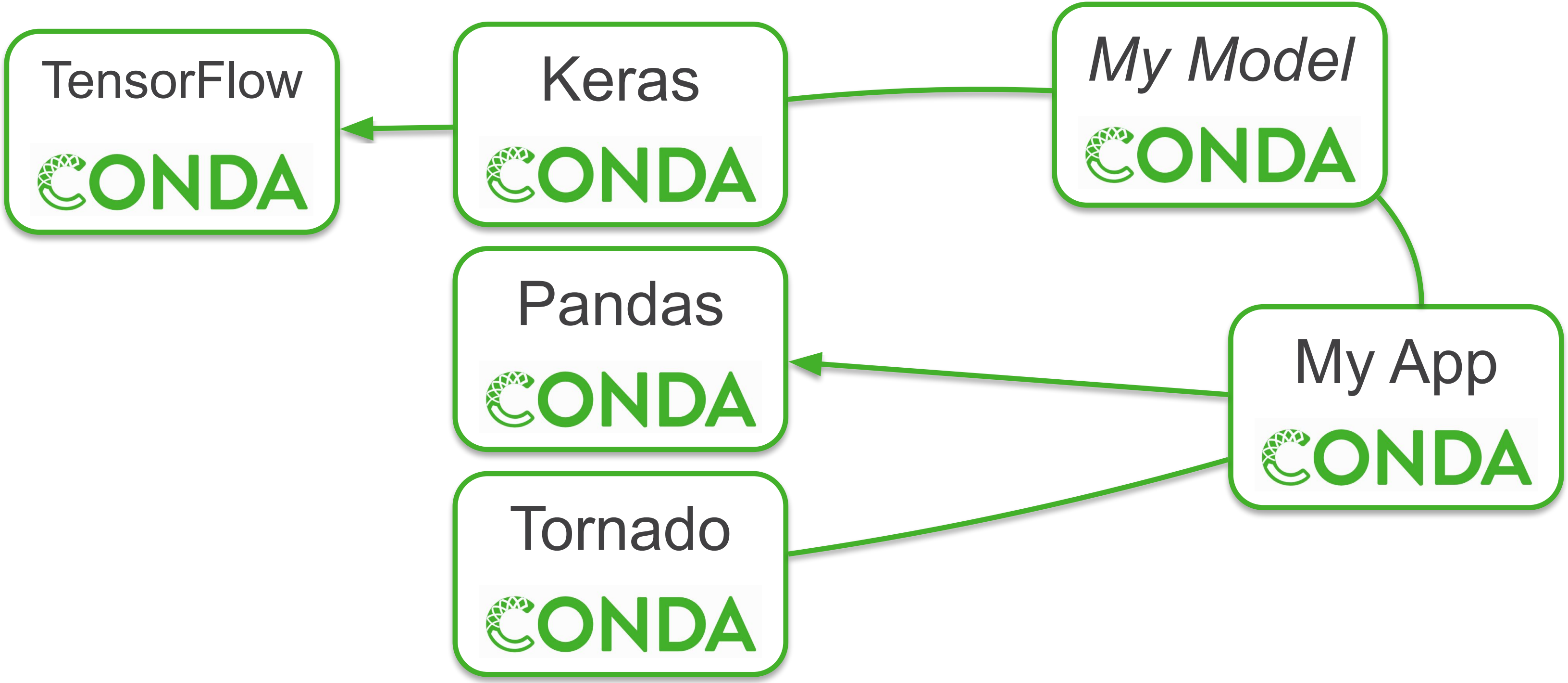


Inference in batches, or one at a time?

Do you need a GPU in production?

Smaller GPUs may also be be sufficient

Packing Models with Conda



A Data Scientist's Job Is Never Done

- Important to monitor deployed models:
  - Does accuracy on new data match training/validation data?
  - Snapshot incorrect predictions for study
  - Keep expanding your training data
  - *Make sure any data collection complies with your security and privacy policies*
- Version your models, just like software!

Exercise 3: Transfer Learning / Loading & Saving Models

Conclusion

The Process

1. Define your problem
2. Identify your dataset
3. Design a network
4. Train the network
5. Check your work and iterate as needed
6. Package for production
7. Monitor deployed models for effectiveness

GPU Requirements: Hardware & OS

- **NVIDIA GPU**
  - Best results: Pascal, Volta, or Turing architectures, >4 GB of GPU memory
  - Suggestions:
    - GeForce: GTX 1070, GTX 1080, RTX 2070, RTX 2080
    - Titan: Xp, V, RTX
    - Quadro: many models
    - Tesla: P100, V100
  - *You can use older GPUs to learn, but don't expect great performance.*
- **CPU:**
  - Quad core
  - 2x more CPU memory than your GPU
- **OS:**
  - Linux 64-bit is preferrable
  - Windows 64-bit also works
  - macOS: no suitable NVIDIA GPUs in Macs made since 2014, external NVIDIA GPUs not officially supported, CUDA drivers incompatible with macOS 10.14

- *Can also use cloud servers!*

Cloud Availability

Tesla K80

- Two GPUs on one card
- 2 x 2496 CUDA cores @ 0.56 GHz
- 2 x 12 GB memory
- *Released: Nov 2014*

Azure, Google Cloud Platform, aws

Tesla P100

- 3584 CUDA cores @ 1.3 GHz
- 16 GB memory
- 732 GB/sec
- NVLink 1
- *Released: April 2016*

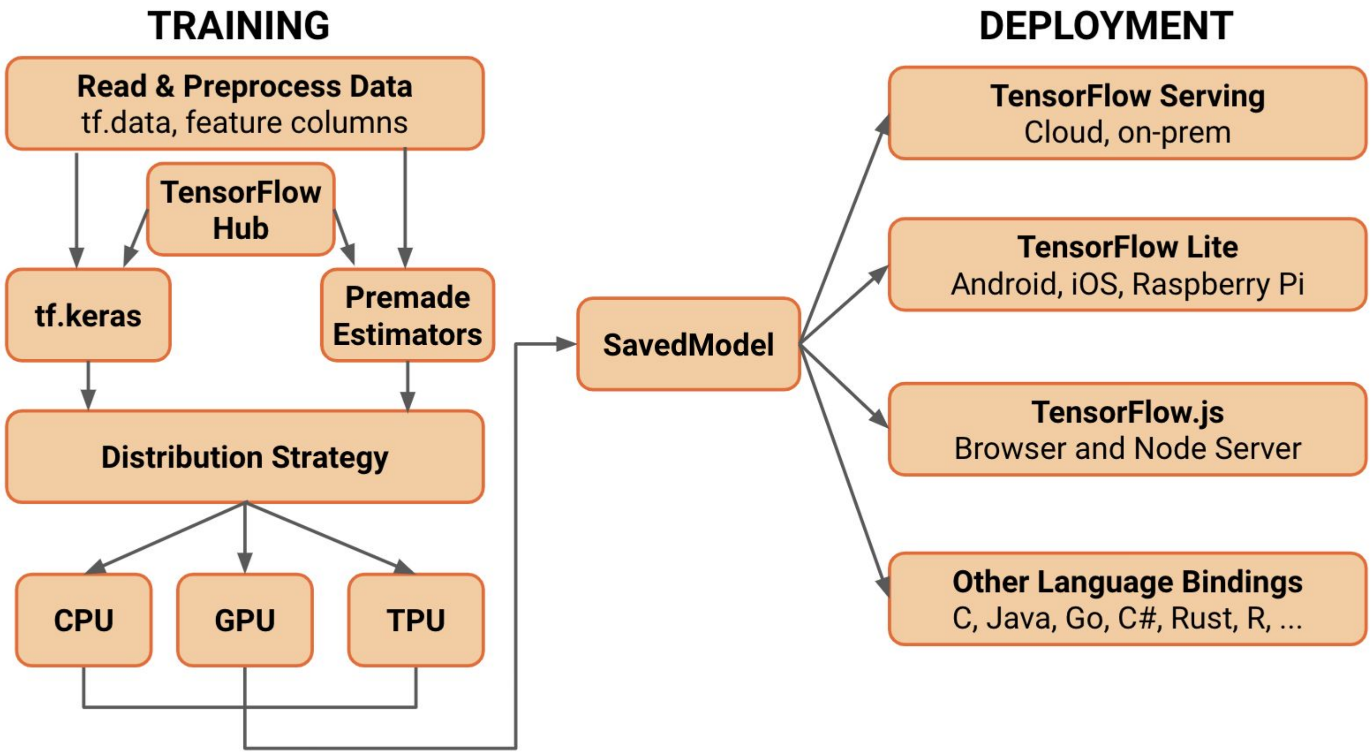
Azure, Google Cloud Platform

Tesla V100

- 5120 CUDA cores @ 1.3 GHz
- 16/32 GB memory
- 900 GB/sec
- NVLink 2
- Tensor Cores for DL
- *Released: June 2017*

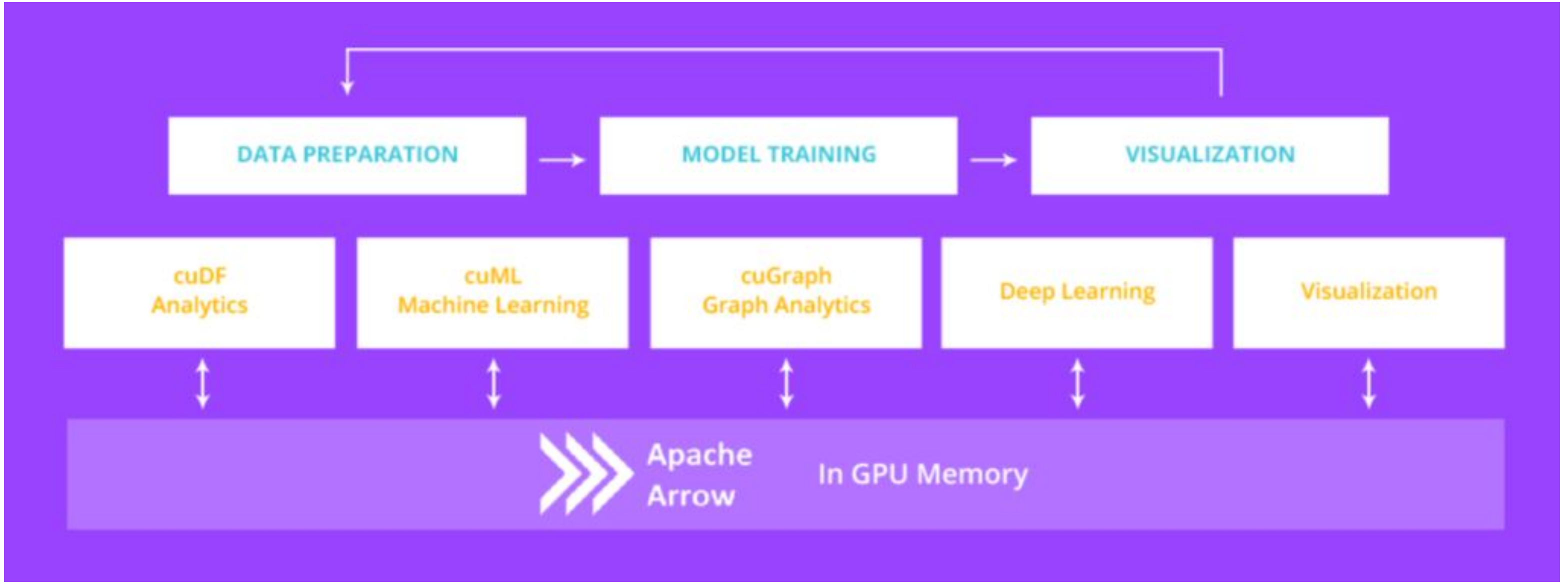
Azure, Google Cloud Platform, aws

Learn More: TensorFlow



https://medium.com/tensorflow/whats-coming-in-tensorflow-2-0-d3663832e9b8

Learn More: RAPIDS



GPU-accelerated dataframes and traditional ML algorithms

https://medium.com/rapids-ai/the-road-to-1-0-building-for-the-long-haul-657ae1afdfd6

Further Reading on Deep Learning

- **Tutorial Notebooks:**
  https://github.com/ContinuumIO/ac2020-dl-gpu
- *Deep Learning with Python*, by François Chollet
  https://www.manning.com/books/deep-learning-with-python
- Neural Network Playground (experiment in your browser!)
  http://playground.tensorflow.org/
- Keras Documentation
  https://keras.io/
- **Want code examples? Google search for "Keras [use case]".**
  Examples:
  "keras image segmentation"

Thank you.