Image Recognition with MNIST

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Learning Goals

- How does image recognition work?
- What is MNIST?
- How do I build a machine learning model to recognize and classify images with Tensorflow?
- How do I build a machine learning model to recognize and classify images with Keras?

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What do you Need Going in?

- Some Python and numpy knowledge
- A Python development environment (we will use Anaconda and Jupyter notebooks)
- An understanding of how machine learning works
- Some experience with Tensorflow
- Ideally, part 1 of this course (Intro to Machine Learning)

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What Topics will we Cover?

- Intro to image recognition
- Intro to MNIST
- Build, train, and test an MNIST image recognition model
- Build, train, and test an MNIST image recognition model with Keras

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Why Image Recognition?

- Image recognition is a fun and relatable topic
- There are many practical applications for recognizing and classifying images
- Once we understand how to build the model, it is easy to expand into other areas
- MNIST is an easy to use dataset

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Intro to Image Recognition

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What will we Cover?

- What is image recognition?
- What tools can help us to solve it?

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What is Image Recognition?

- Image recognition is seeing an object or an image of an object and knowing what it is
- We essentially class everything that we see into certain categories based on attributes
- Even if we see something we have never seen before, we can usually place it in some category
- For example, if we see a brand new model of car for the first time, we can tell that it is a car by the wheels, hood, windshield, seats, etc.

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How does this work for us?

- A lot of the time, image recognition for us happens subconsciously
- We don't necessarily acknowledge everything that is around us
- However, when we need to notice something, we can usually pick it out and define and describe it
- Knowing what something is is based entirely on previous experiences
- Some things we memorize, others we deduce based on shared characteristics that we see in things we do know

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How does this work for us?

- Subconsciously we separate the items we see based on borders defined primarily by differences in colour
- Example: it is easy to see a green leaf on a brown tree but hard to see a black cat against a black wall
- We also don’t necessarily need to look at every part of an image to know what some part of it is
- Example: if we see only an eye and an ear of someone’s face, we know we are looking at a face

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How does this work for Machines?

- Machines do not have infinite knowledge of what everything they see is
- They only have knowledge of the categories we have taught them
- For example, if you create facial recognition, it only classifies images into faces or not faces
- Even the most sophisticated image recognition models cannot recognize everything and have been trained only to look for certain objects

How does this work for Machines?

- To a machine, an image is simply an array of bytes
- Each pixel on an image contains information about red, green, and blue colour values
- If an image is just black or white, the value for each pixel is simply a darkness value, typically with 255 as white and 0 as black

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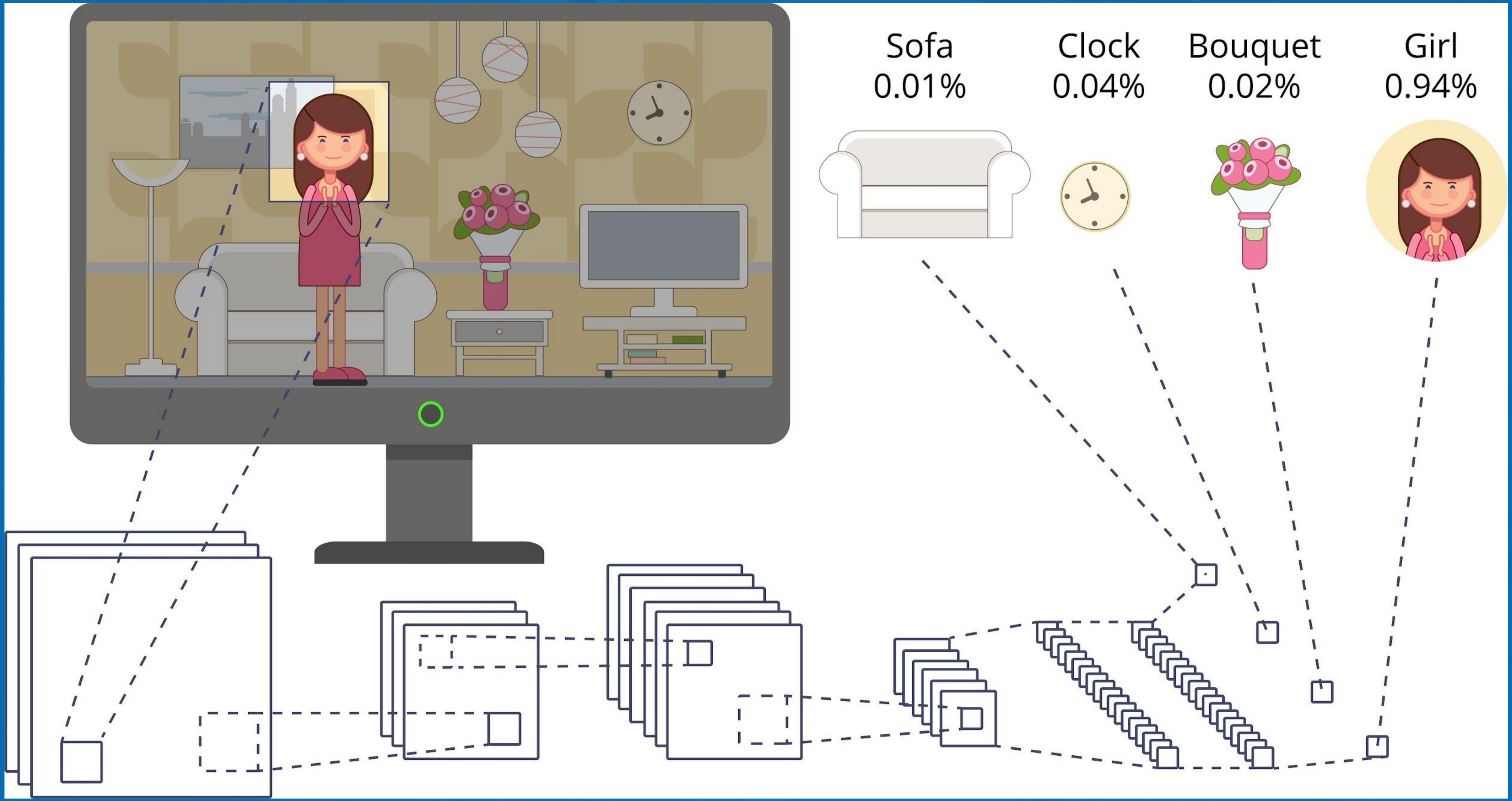
How does this work for Machines?

- Machines don’t care about seeing an image as a whole
- To process an image, they simply look at the values for each of the bytes and look for patterns
- In this way, image recognition models look for groups of similar byte values across images to place an image in a specific category
- For example, high green and brown values in adjacent bytes may suggest an image contains a tree. If many images all have similar groupings of green and brown values, the model may think they all contain trees

How does this work for Machines?



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Tools to Help with Image Recognition

The Problem with Processing Images

- Processing an entire image at a time is a lot
- Most images fed into simple models are small (MNIST images are 28x28 pixels)
- Even this leaves 784 pixels to examine and it's difficult to recognize consistent patterns when comparing all 784 pixel values of one image to another
- Even if we are looking at two images of the same thing, slight position or size changes or slightly different shapes could lead to a mislabelling

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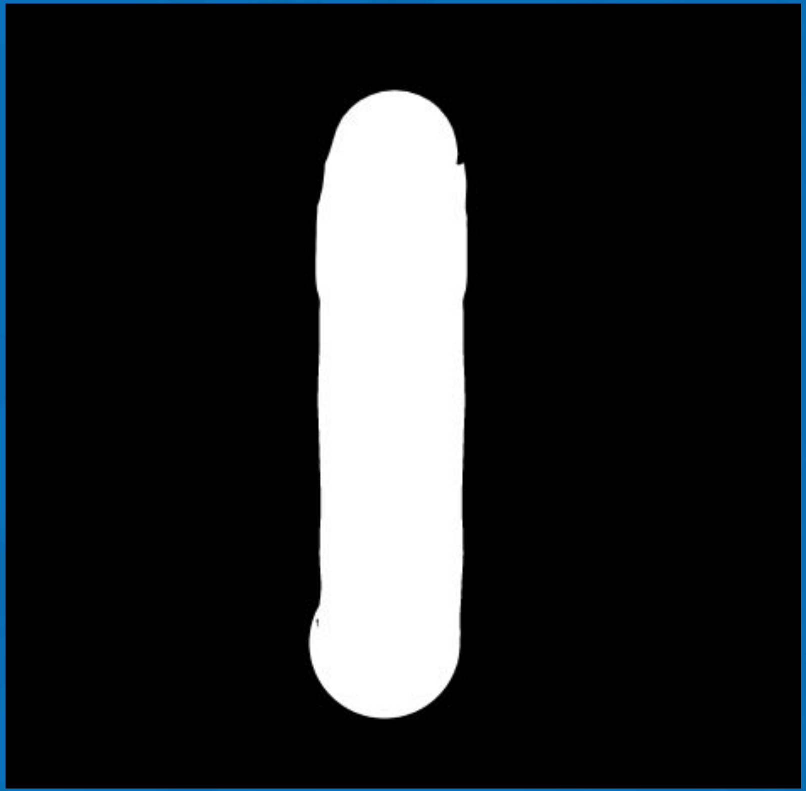
Image as a Machine sees it

```
[[0,0,0,0,0],
 [0,0,255,0,0],
 [0,0,255,0,0],
 [0,0,255,0,0],
 [0,0,0,0,0]]
```



How Machines Solve this

- Machines solve this problem by first breaking down images into smaller parts and processing them instead
- It starts by applying a sort of a filter to different parts of the image a few pixels at a time to produce several smaller, distorted images
- Next, it makes the pieces more abstract by averaging together smaller squares of pixel values
- This ultimately turns this image into something that may not be recognizable by humans but the machines can make sense of it

Convolutional Neural Networks

- The process of breaking down images and applying the filters is done in a **convolutional layer** in a neural network
- Averaging the values to further distort images is done through a **max pooling layer**
- **Convolutional Neural Networks** get their name from the fact that they have one or more convolutional layers
- These are very popular in image recognition models, although RNNs have also performed well

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Convolutions

- **Convolution:** an operation on two functions to produce a third function that explains how the shape of one is modified by the other
- **Image Convolution:** applying a **kernel** or **convolution mask** to blocks of pixels to apply an effect
- Often used to blur or sharpen images, or detect edges
- A **Kernel** is a matrix used as a mask to image pixel values
- Kernels are often pre-determined through Tensorflow objects

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Convolution

Image:

[[0,0,0,0,0],
 [0,0,255,0,0],
 [0,0,255,0,0],
 [0,0,255,0,0],
 [0,0,0,0,0]]

Kernel:

[[0,-1,0],
 [-1,5,-1],
 [0,-1,0]]

First result:

[[, ,],
 [,-255,],
 [, ,]]

Max Pooling

- **Max Pooling**: replacing a block of pixels by one pixel with the highest value out of the block
- Makes an image more abstract
- Used to downsize an image and also prevent overfitting (drawing conclusions when there are none)
- Generally we specify the size of the matrix and the step size (number of pixels to skip over when applying the next max pool

Max Pooling

Original

[[5,10,15,10],
 [15,20,10,12],
 [13,16,9,8],
 [15,19,25,20]]

Final Result

[[20,15],
 [19,25]]

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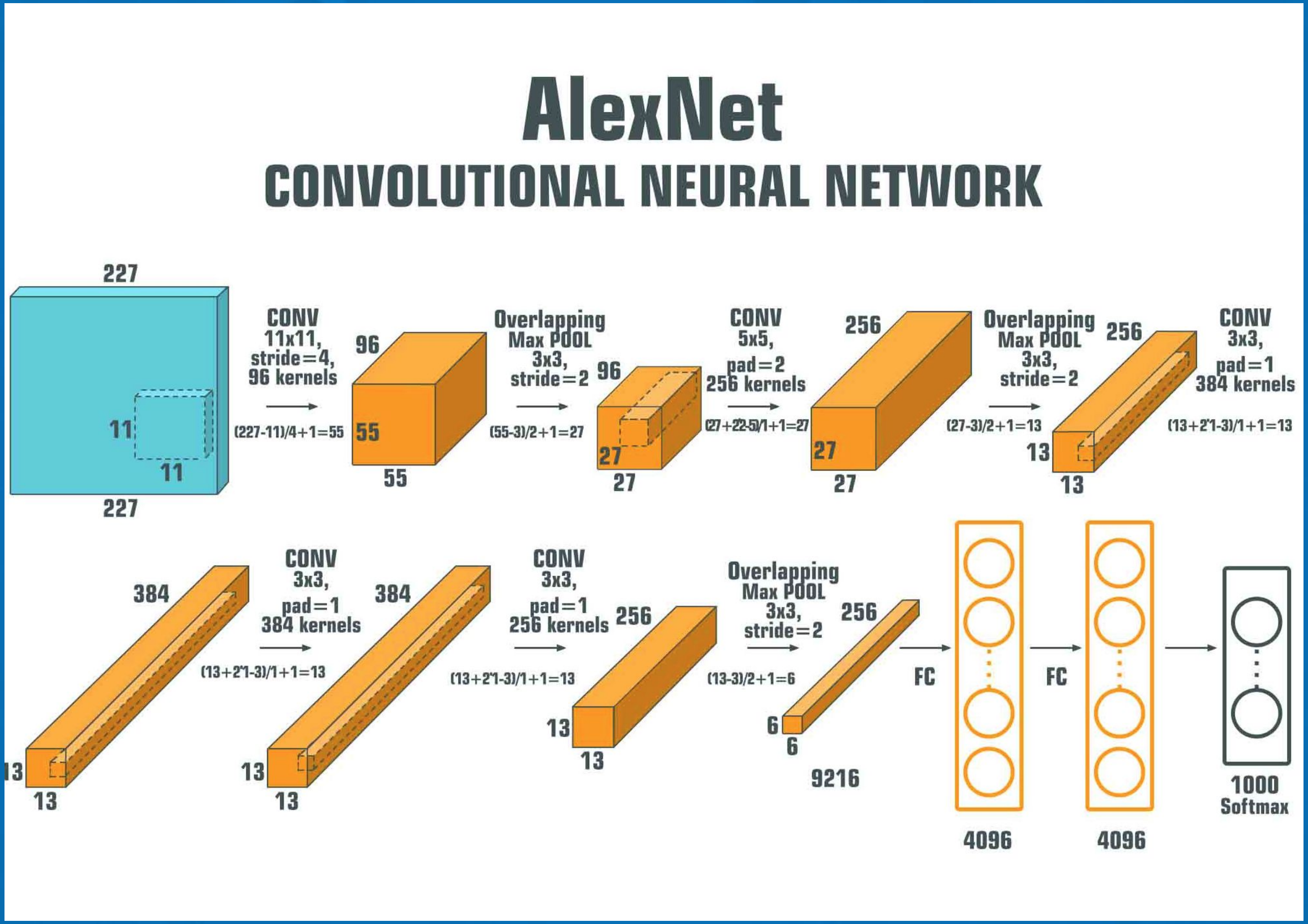
Putting it Together

- Almost all convolutional neural networks will have a convolutional layer followed by a max pooling layer
- Larger networks will repeat this one or more times along with other layers to perform additional processing
- The result of the two layers is a set of smaller, more abstract images comprised of parts of the original image
- The purpose is to cut out unnecessary image noise and to focus on the stand-out features so that the model can focus on what is important

Putting it Together



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MNIST

What is MNIST?

- MNIST = Modern National Institute of Standards of Technology
- We will use the dataset that MNIST is famous for
- The dataset contains 70,000 images of handwritten digits
- The even more modern EMNIST dataset was released in 2017 that contains 280,000 images

How are Images Formatted?

- 60,000 training images and 10,000 testing images
- Each image is 28x28 pixels (784 total)
- Each image is black and white
- Each image is labelled based on which image it represents
- Each label is in one-hot encoding form
- Instead of a string label, we have an array of 0s and 1s with the 1 in the position that represents the digit and 0s in the rest

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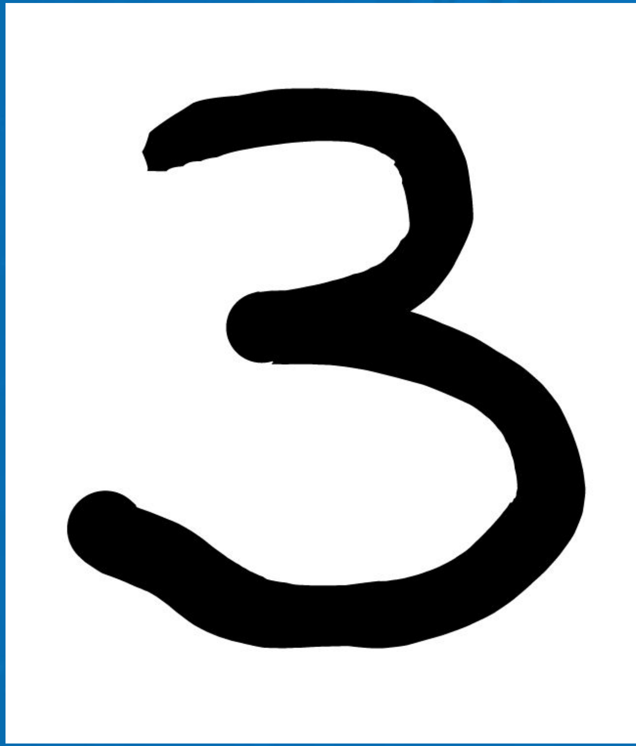
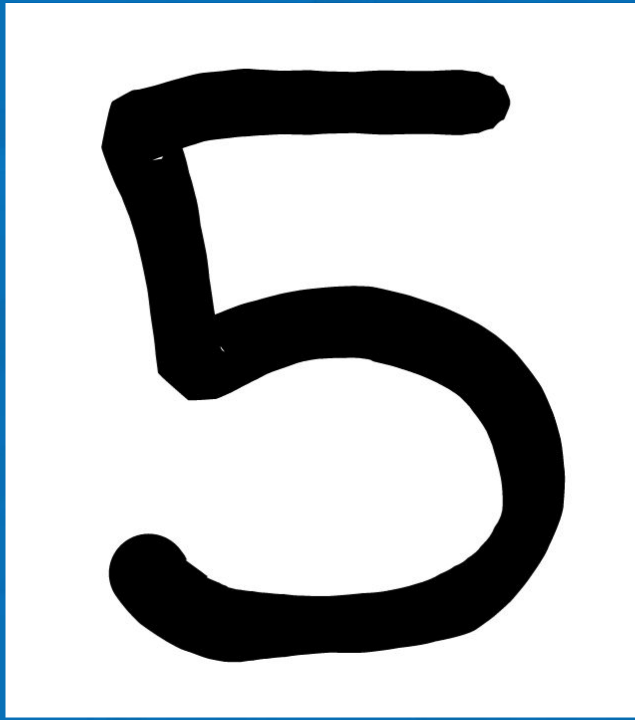
How are the Images Formatted?





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Why Bother with MNIST?

- Very highly esteemed data set
- Starting point for many image recognition models
- Great way to learn how to build an image recognition/classification model with a trusted and pre-formatted data set
- Ongoing competition to see who can get the best results (best so far is 0.21% error rate achieved by an ensemble of 5 CNNs produced by The Parallel Computing Center)

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Building a CNN with Tensorflow Part 1

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Part 1 - Obtaining Data

- Download MNIST dataset
- Examine images
- Examine labels

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Building a CNN with Tensorflow Part 2

Part 2 - Layers

- Convolution layer
- Flatten layer
- Dense layer

Building a CNN with Tensorflow Part 3

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Part 3 - Loss and Optimizer

- Add a loss function
- Add an optimizer function
- Add a way to measure loss and accuracy

Building a CNN with Tensorflow Part 4

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Part 4 - Train and Test Step

- Add the function to run when training the model
- Add the function to run when testing the model

Building a CNN with Tensorflow Part 5

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Part 5 - Formatting Data

- Format our inputs
- Format our outputs

Building a CNN with Tensorflow Part 6

Part 6 - Training

- Write the train loop
- Train and evaluate the model

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Keras

What is Keras?

- **Keras** is a higher level machine learning library aimed at rapid construction and deployment of neural networks
- Provides a more abstract interface
- Takes a more more modular approach by grouping functionality into objects
- Can run with a Tensorflow, MCT, Theano, or PlaidML backend but we default and most popular is Tensorflow

Why use Keras?

- In short: Keras is easier to use than raw Tensorflow
- The modular approach makes it easy to build a model layer by layer
- Built in functions to train, test, and evaluate models
- Becoming more commonplace than raw Tensorflow
- Tensorflow 2.0 is closely integrated with Keras and calls upon Keras functionality in many models and datasets

How do we Obtain Keras?

- Keras should already come with Tensorflow
- Can be found under the module tf.keras
- Many parts of the Tensorflow ecosystem are now tf.keras.something

Building a CNN with Keras

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Steps

- Obtain the data
- Add the model
- Add the layers
- Train the model
- Test the model

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- How do I build a machine learning model to recognize and classify images with just Keras?

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What Topics did we Cover?

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Where to go from here

- Improve upon our model by modifying structure
- Try other image recognition data sets like CIFAR
- Try image recognition with RNNs or other types of neural networks
- Explore other types of neural networks and try solving different problems with them
- Keep exploring the Tensorflow and Keras ecosystem!

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