CONVOLUTIONAL NEURAL NETWORKS

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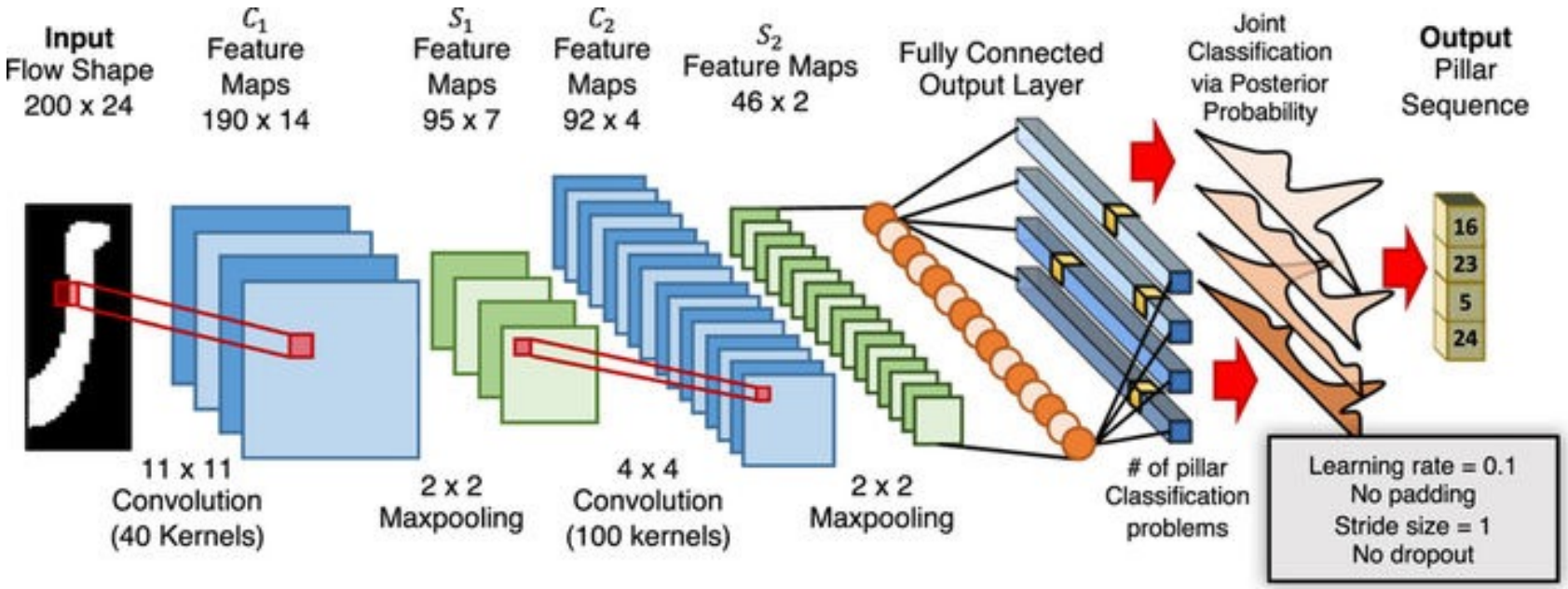
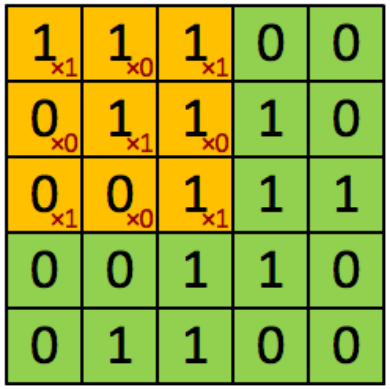
Convolutional Neural Networks
Revision: What is a CNN?

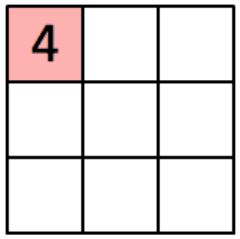


Convolutional Neural Networks
Convolution Layers

- **The CNN's primary distinguishing feature is the convolution layer.**
  - Made up of kernels that convolve over the input and over each other.



Image



Convolved Feature

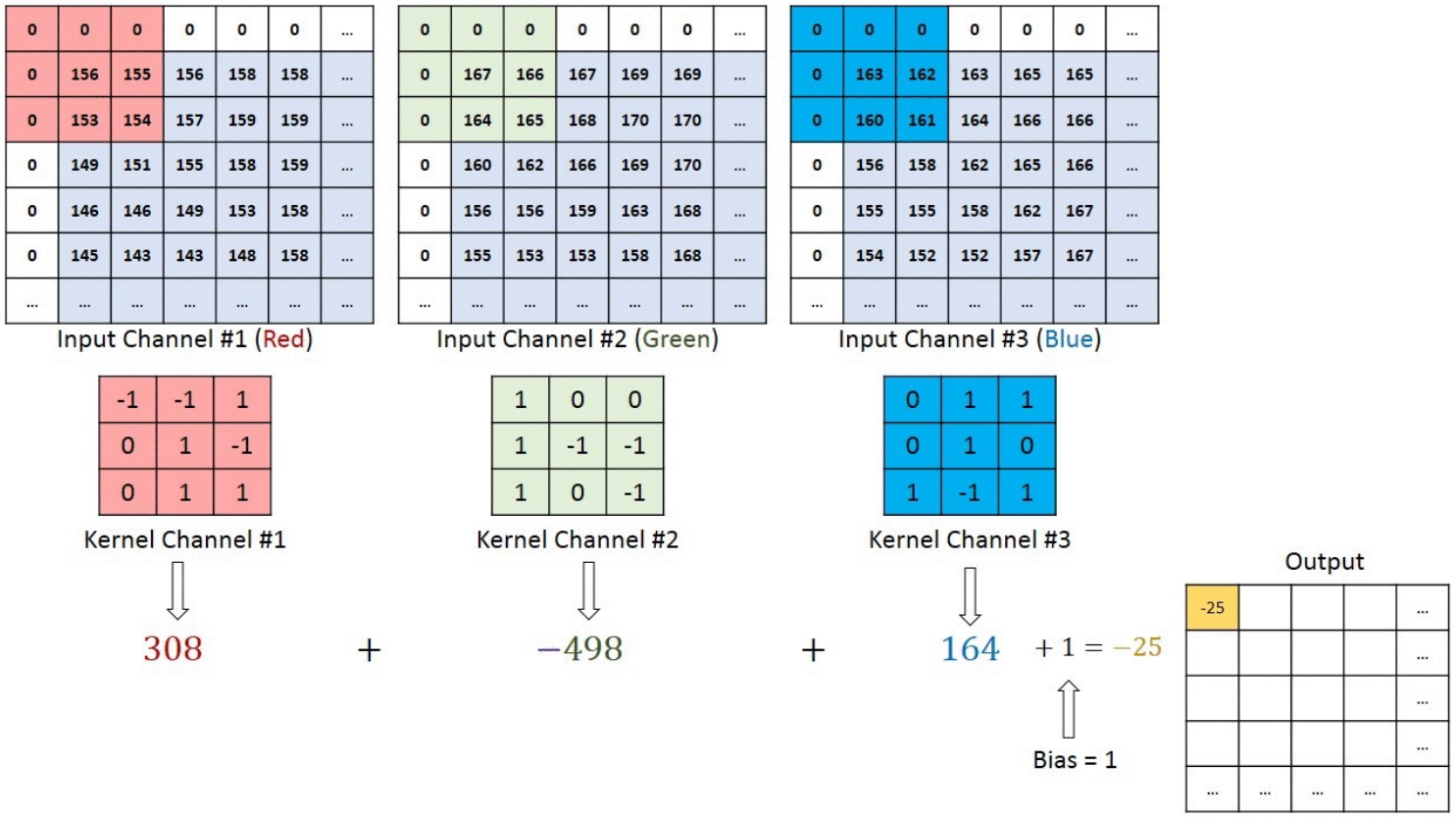
```
Kernel/Filter, K =

1  0  1
0  1  0
1  0  1
```

$$(I * K)_{xy} = \sum_{i=1}^{h} \sum_{j=1}^{w} K_{ij} \cdot I_{x+i-1,y+j-1}$$

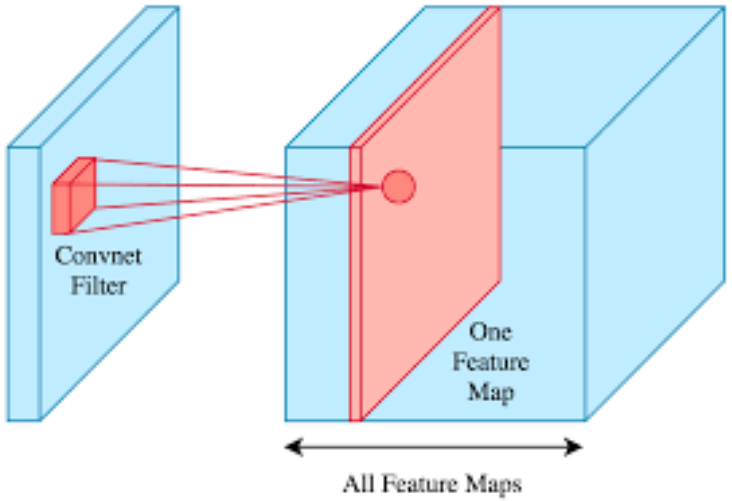
Convolutional Neural Networks
Convolution Layers

- **The depth of the kernel is equal to the depth of the data. E.g. with color images there are 3 channels, and the kernel is 3 layers deep:**



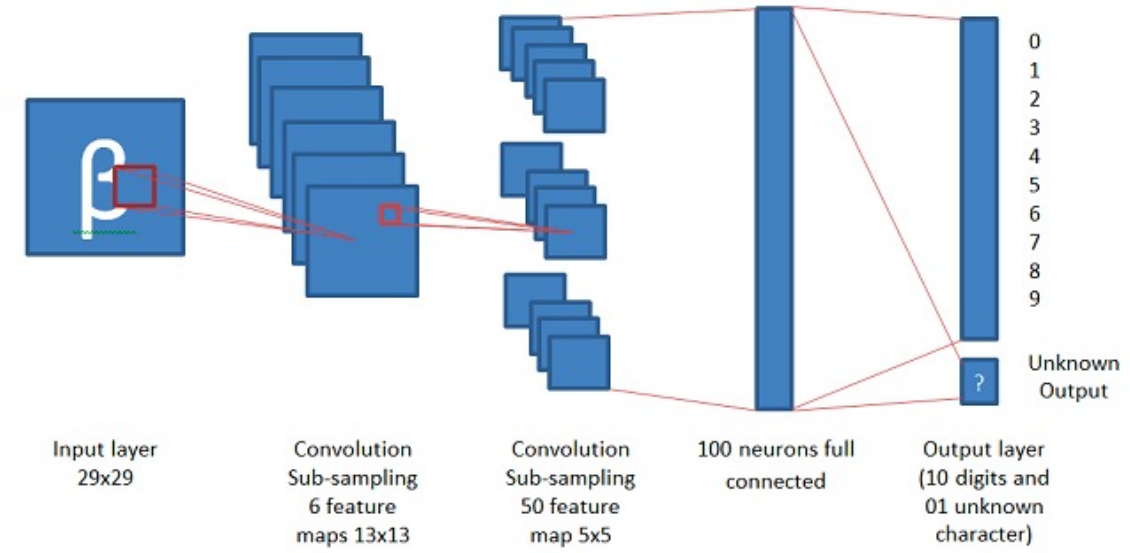
Convolutional Neural Networks
Convolution Layers

- **The kernels function as feature extractors and the output from the convolution operation is called a "feature map"**
  - As training progresses the kernels become optimized to extract key information like edges, repeating patterns, etc. in the input data.
- **Many kernels can be used on one layer.**
  - This will produce a volume of feature maps instead of a single feature map.
  - Due to the randomness of the initial kernel, each feature map ends up extracting a different feature of the input.



Convolutional Neural Networks
Convolution Layers

- **You can convolve kernels over earlier kernels.**
  - The feature maps generated will represent higher level features of the input.
  - E.g. the lower kernel might extract lines, the higher kernel might extract shapes.



Convolutional Neural Networks
Convolution Layers

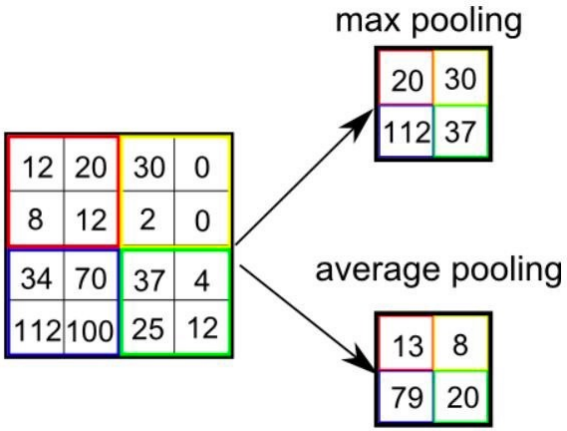
- **Convolution Kernel Hyper-Parameters:**
  - Size:
    - ✓**E.g. 3x3, 5x5, 9x9**
    - ✓**Typically smaller kernels extract more refined features at the expense of higher computational costs. Can be more sensitive to noise.**
    - ✓**Larger kernels use less computational power but produce features of lower resolution.**
  - Stride:
    - ✓**The # of steps a kernel moves to the right or down each time.**
    - ✓**Smaller strides capture more data but also produce larger feature maps.**
    - ✓**Larger strides produce smaller feature maps but lose more data.**
  - Padding:
    - ✓**What do we do when we reach the end of the input data and part of the kernel "hangs out" over the edge?**
    - ✓**Keras supports a "same" padding that preserves the size of the input. Other choices may increase or decrease the size of the input.**

Convolutional Neural Networks
Convolution Layers in Keras

- **Keras offers many types of convolution layers: https://keras.io/layers/convolutional/**
  - padding:
    - ✓**'valid': Convolution stops when the right/bottom edge of the filter hits the right/bottom edge of the input data. Will create a feature map smaller than the input**
    - ✓**'same': Input is padded with '0' to allow the feature map to be the same size as the input.**
  - activation:
    - ✓**If None, Keras will use an identify activation. I.e. id(x) = x, where x is the feature map computed by the convolution operation.**
    - ✓**Otherwise can specify other activations like ReLU, tanh etc.**
  - kernel_size:
    - ✓**Size of the kernel window. E.g. (3, 3) makes a 3x3 filter**
  - filters: Number of kernels to make.

Convolutional Neural Networks
Pooling Layers

- **The pooling layer takes a n x n region of the feature map and either picks the maximum or takes an average:**



- **Pooling layers:**
  - Reduce dimensionality and hence computing power.
  - Extracts the most dominant features (max pooling):
    - ✓**Makes the model shift invariant and less noise sensitive**
  - averages the features (average pooling)
    - ✓**Reduces the effect of noise by averaging it out – white noise has an average of 0.**

Convolutional Neural Networks
Pooling Layers

- **Pooling layer hyperparameters:**
  - stride: As with the convolution layer, this determines the number of steps the pool moves each time to the right or down.
  - size: Controls the dimensionality reduction.
    - ✓**Generally if stride = size, the feature map is reduced by 1/size in each dimension.**
  - Keras pooling API: https://keras.io/layers/pooling/
    - ✓**pool_size: The length or dimensions of the pool.**
    - ✓**strides: As described above.**
- **Generally the first few (or many?) layers of the CNN consist of alternating convolution and pooling layers:**
  - However stacking too many pooling layers can result in losing all data.

Convolutional Neural Networks
Flatten Layer / Example

- **The Flatten layer turns the feature maps into a 1D vector for feeding into the Dense layers.**
- **Example:**

```
model = Sequential()
model.add(Conv2D(32, kernel_size=(5,5),
activation='relu',
input_shape=(28, 28, 1), padding='same'))

model.add(MaxPooling2D(pool_size=(2,2), strides=2))
model.add(Conv2D(64, kernel_size=(5,5), activation='relu'))
model.add(Conv2D(128, kernel_size=(5,5), activation='relu'))
model.add(Conv2D(64, kernel_size=(5,5), activation='relu'))
model.add(MaxPooling2D(pool_size=(2,2), strides=2))
model.add(Flatten())
model.add(Dense(1024, activation='relu'))
model.add(Dropout(0.1))
model.add(Dense(10, activation='softmax'))
```