NUS-ISS
Problem Solving Using Pattern Recognition

Convolutional neural network

by Dr. Tan Jen Hong

2D convolution

The original

Input

1	3	2	1
1	3	3	1
2	1	1	3
3	2	3	3

Kernel

1	2	3
0	1	0
2	1	2

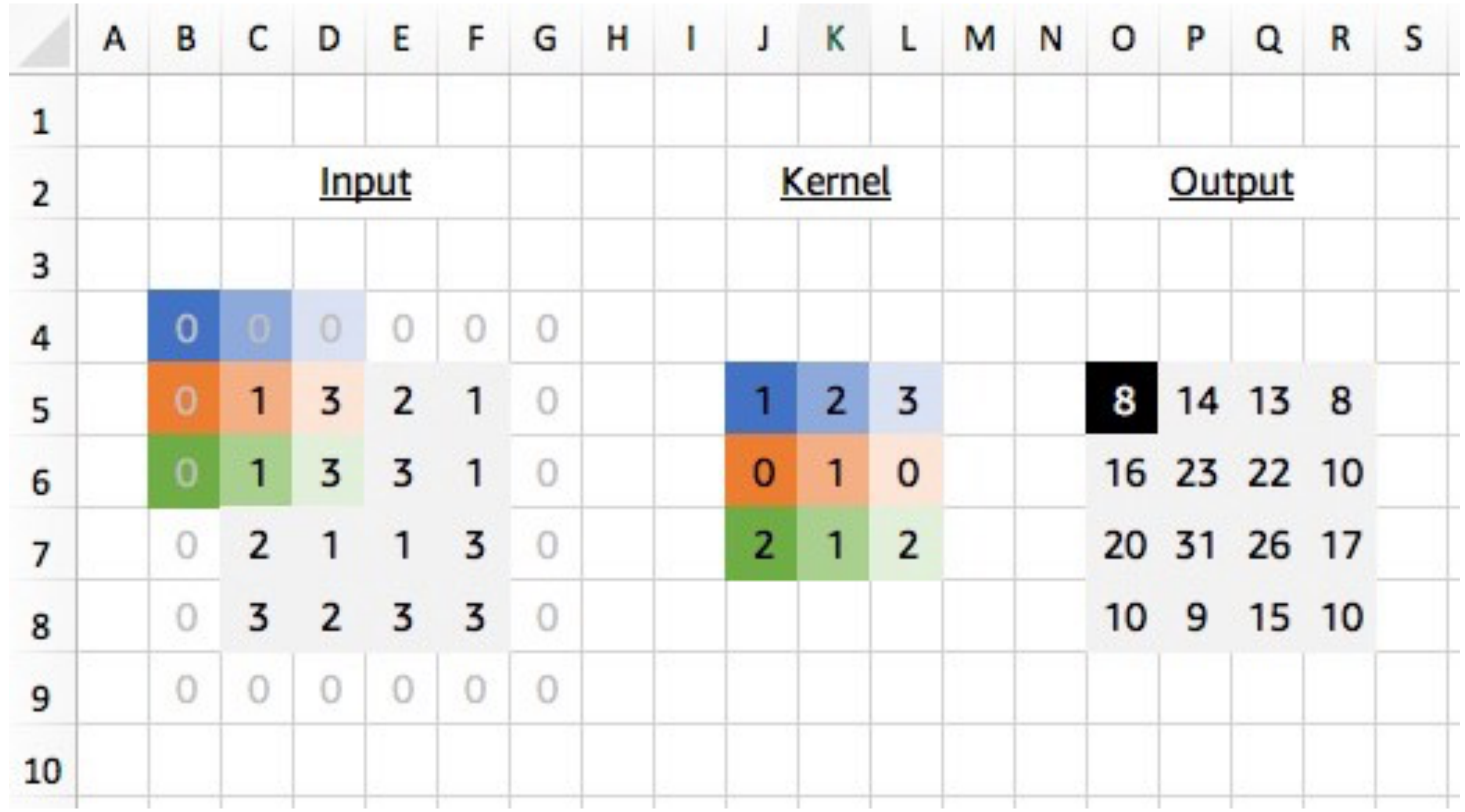
Output

23	22
31	26

Source: https://medium.com/apache-mxnet/convolutions-explained-with-ms-excel-465d6649831c

2D convolution

The padded



Input

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

Kernel

1	2	3
0	1	0
2	1	2

Output

8	14	13	8
16	23	22	10
20	31	26	17
10	9	15	10

Source: https://medium.com/apache-mxnet/convolutions-explained-with-ms-excel-465d6649831c

2D convolution

Multi-channel

Input

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

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

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

Kernel

0	1	0
0	0	2
0	1	0

2	1	0
0	0	0
0	3	0

1	0	0
1	0	0
0	0	2

Intermediate Output

7	5	3
4	7	5
7	2	8

5	3	10
13	1	13
7	12	11

7	5	2
11	8	2
9	4	6

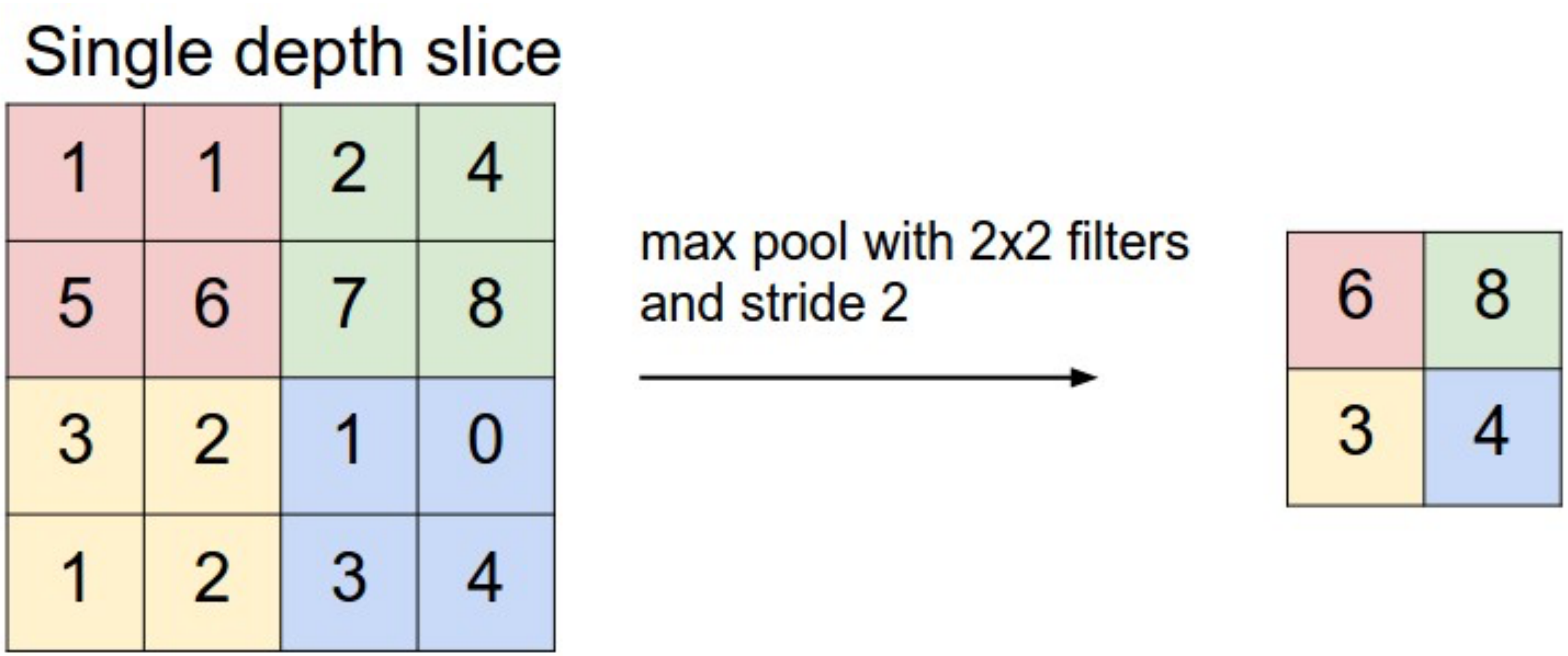
Output

19	13	15
28	16	20
23	18	25

Source: https://medium.com/apache-mxnet/convolutions-explained-with-ms-excel-465d6649831c

Max pooling

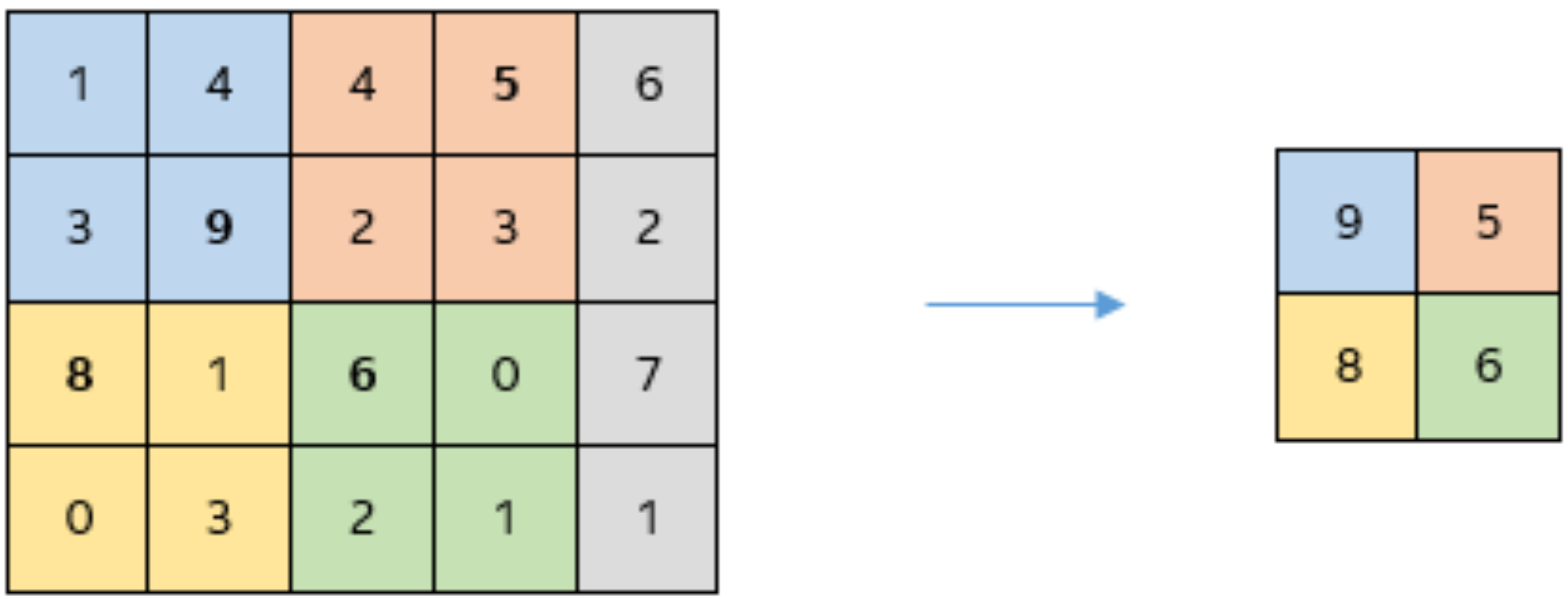
The original



Source: http://cs231n.github.io/convolutional-networks/

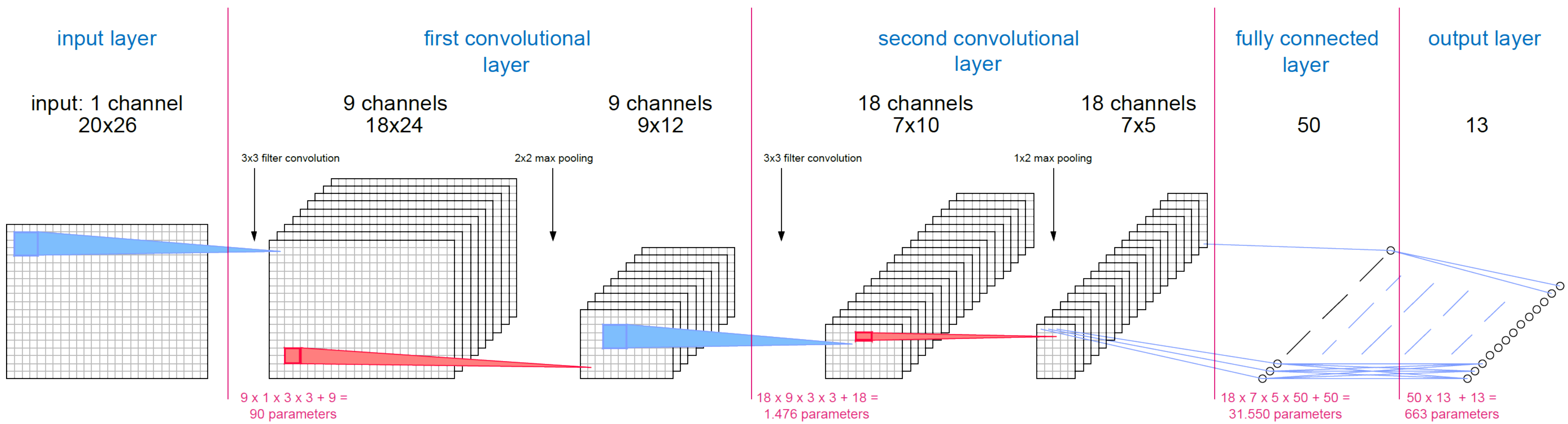
Max pooling

With situation



Source: https://software.intel.com/en-us/daal-programming-guide-2d-max-pooling-forward-layer

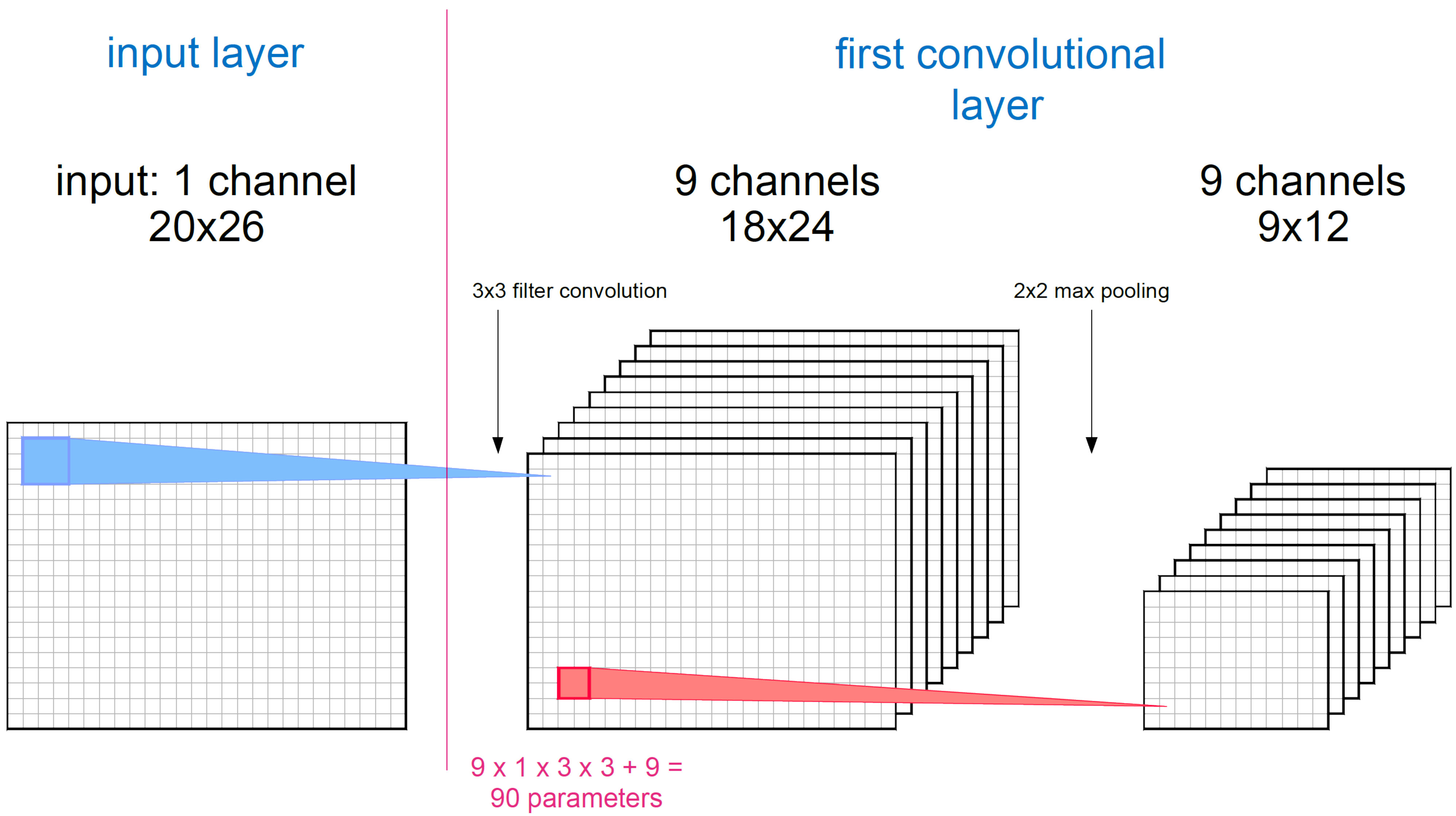
Convolutional neural network
Overview



Source: http://giant.uji.es/blog/convnet/convnet.html

Convolutional neural network

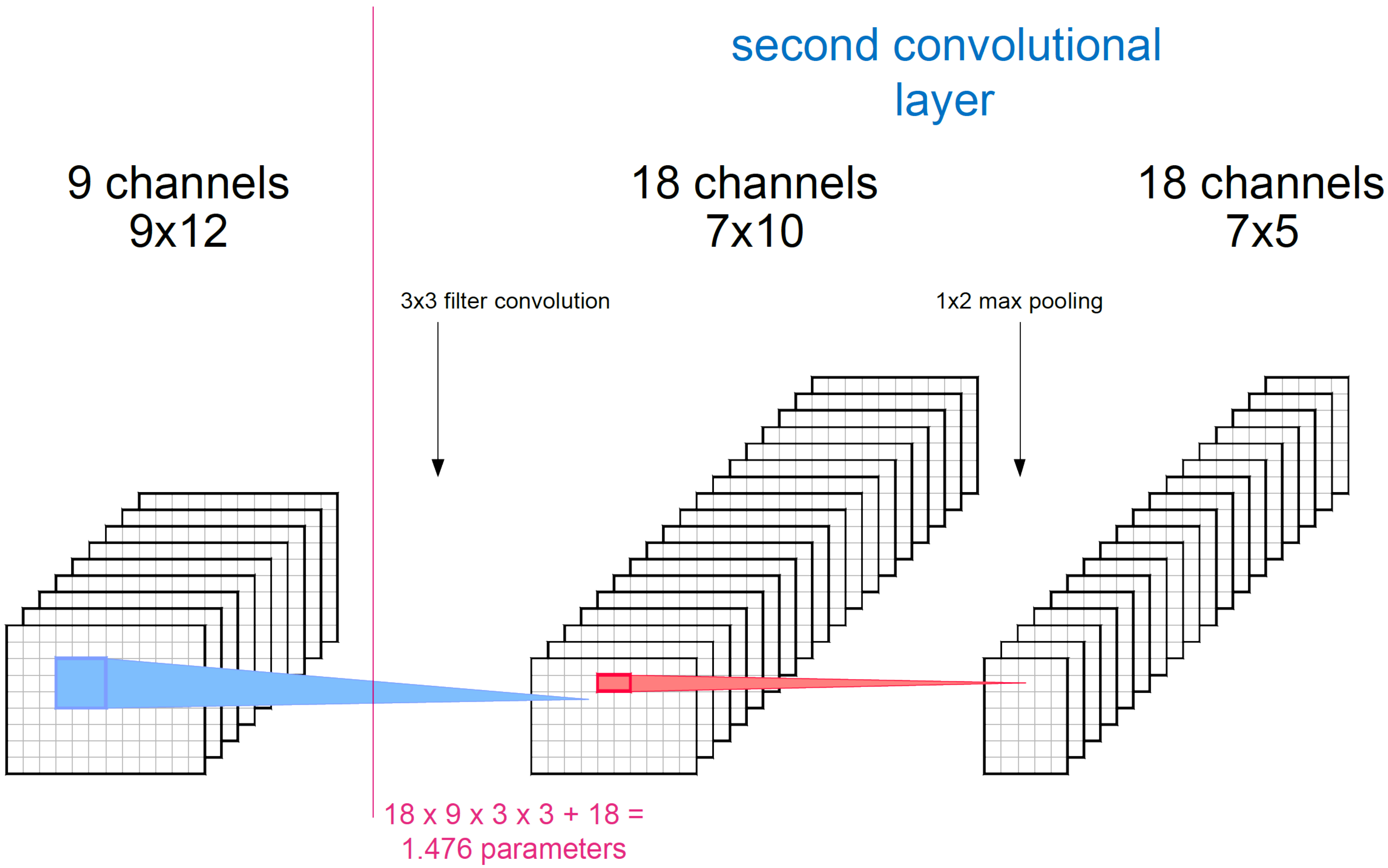
Input to first layer



Source: http://giant.uji.es/blog/convnet/convnet.html

Convolutional neural network

First layer to second layer



Source: http://giant.uji.es/blog/convnet/convnet.html

Convolutional neural network

Second layer to output

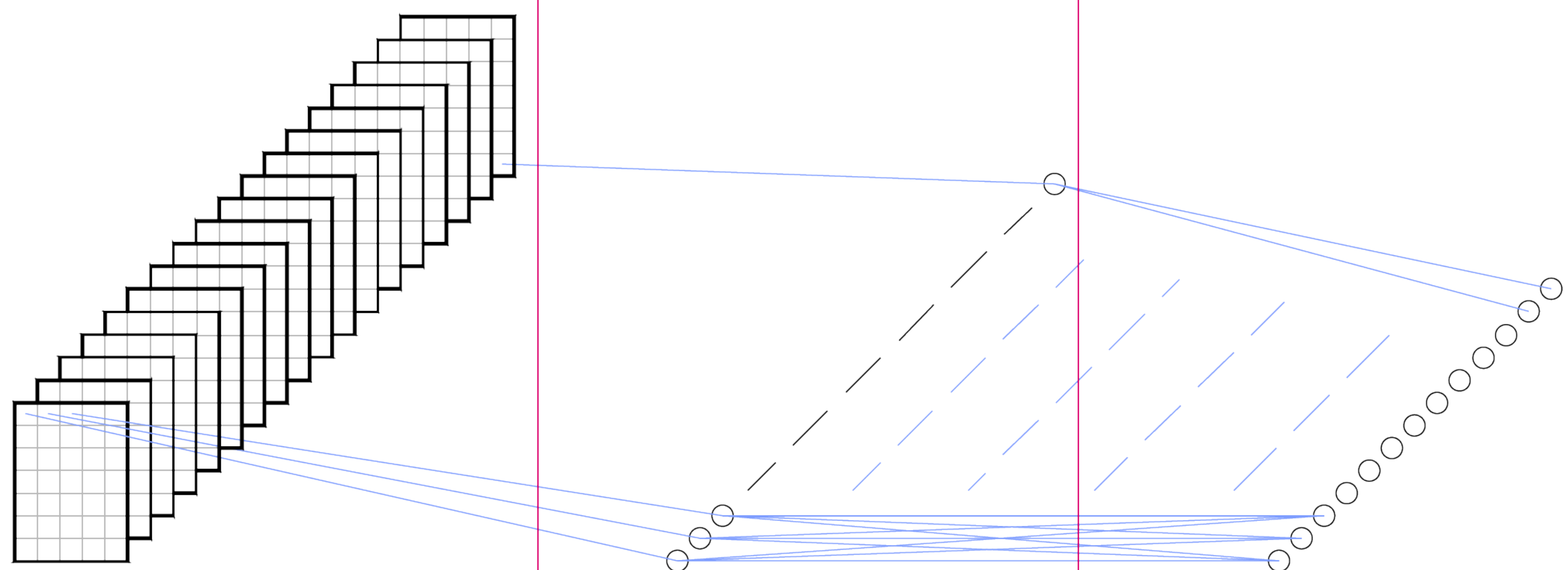
18 channels
7x5

fully connected layer

50

output layer

13



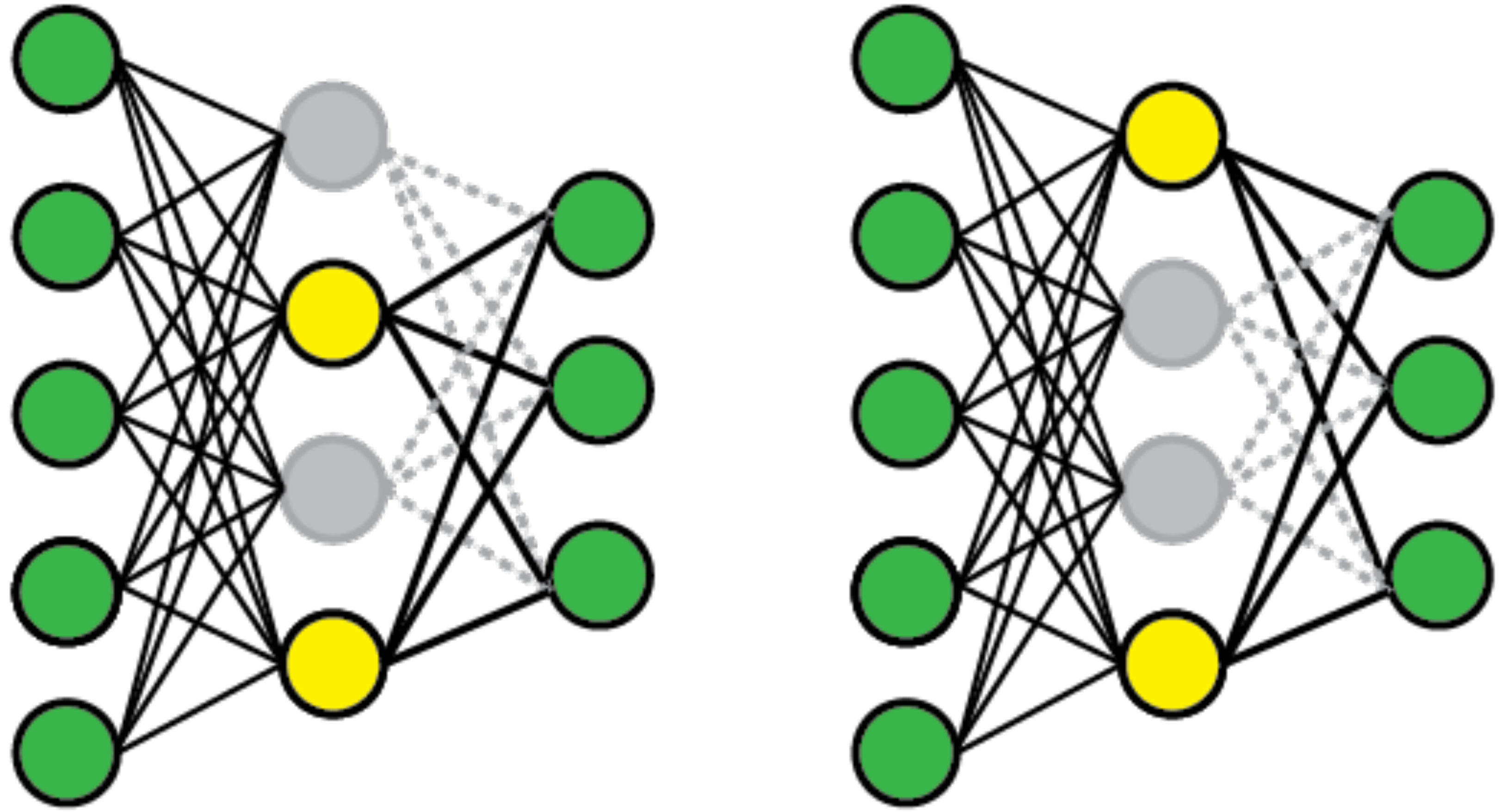
18 x 7 x 5 x 50 + 50 =
31.550 parameters

50 x 13 + 13 =
663 parameters

Source: http://giant.uji.es/blog/convnet/convnet.html

Convolutional neural network

Dropout



Source: https://stats.stackexchange.com/questions/201569/difference-between-dropout-and-dropconnect

Any fans of Japan?

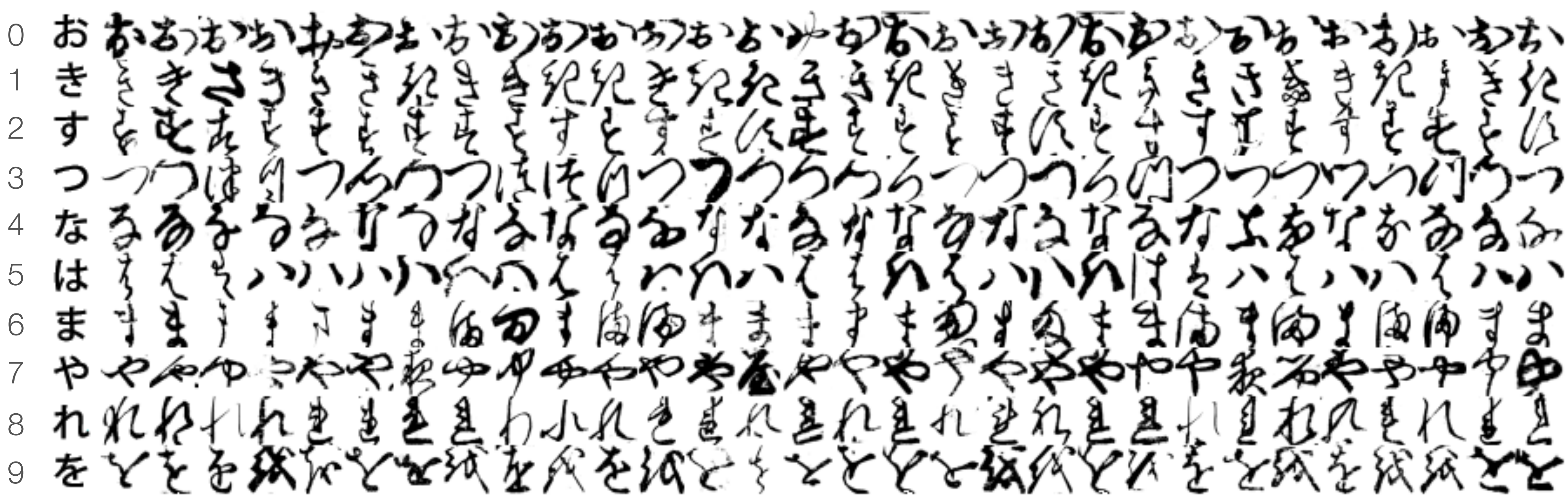
Cursive Kuzushiji

Automated solution?

Source: https://arxiv.org/pdf/1812.01718.pdf

Kuzushiji MNIST

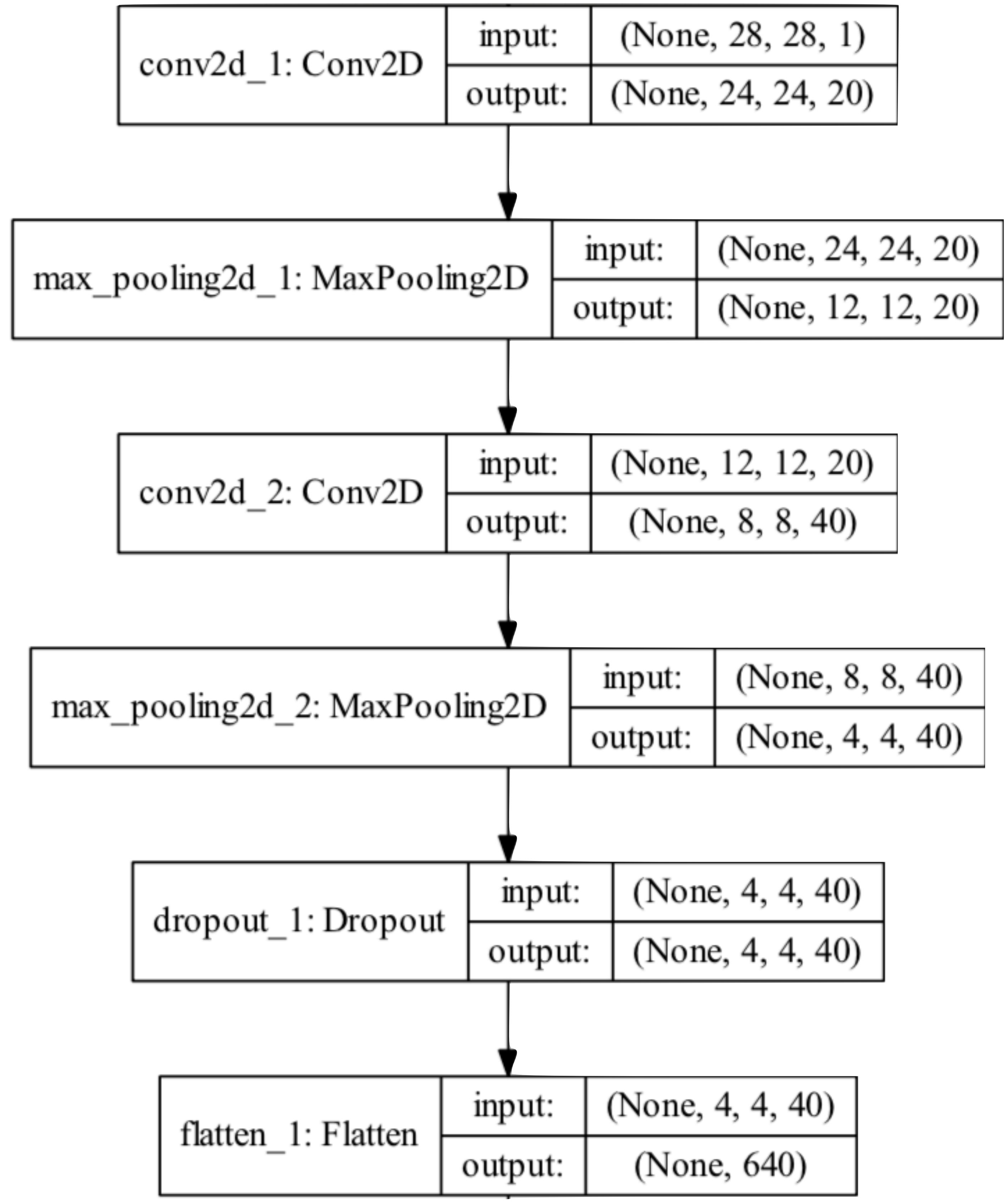
Another 'MNIST' alternative



Source: https://github.com/rois-codh/kmnist/blob/master/images/kmnist_examples.png

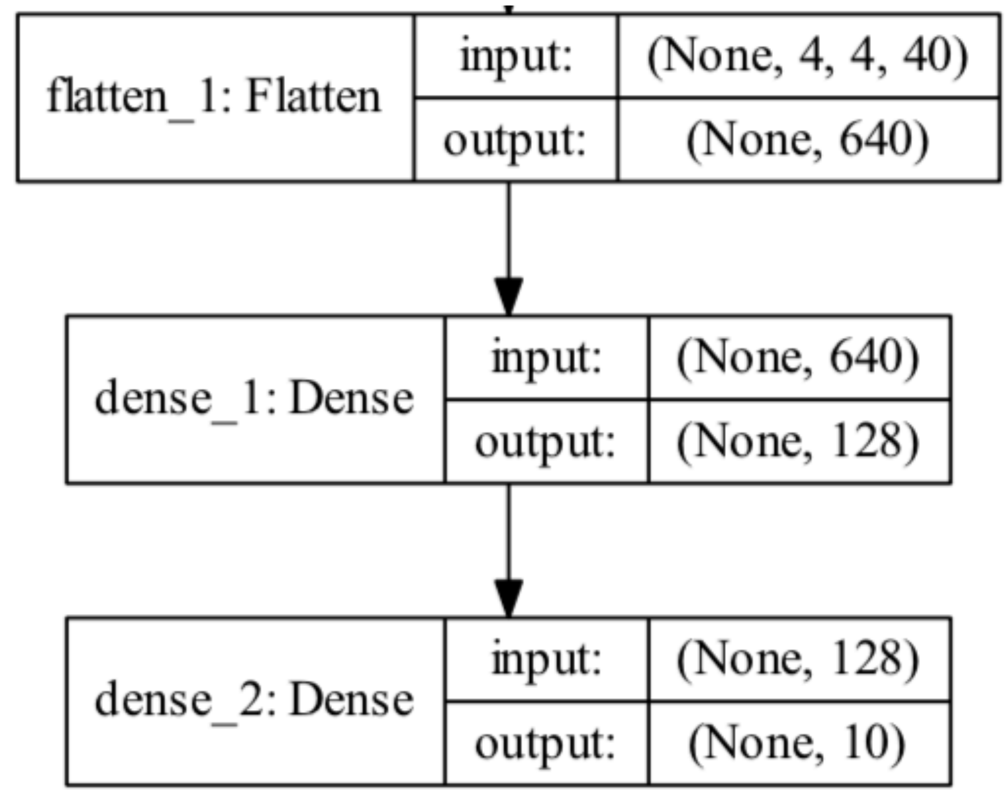
Kuzushiji MNIST

The basic model, part 1



Kuzushiji MNIST

The basic model, part 1



Kuzushiji MNIST

The main layout for the code

1. Import libraries
2. Matplotlib setup
3. Data preparation
4. Define model
5. Train model
6. Test model

Kuzushiji MNIST

1. Import libraries, part 1

- numpy for matrix manipulation; sklearn for measuring performance; matplotlib to show image and plot result; os for path manipulation

```
> import numpy as np
> import sklearn.metrics as metrics
> import matplotlib.pyplot as plt
> import os
```

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1. Import libraries, part 2

- Import all the Keras functions that we are going to use in this problem

```
> from tensorflow.keras.callbacks import ModelCheckpoint,CSVLogger
> from tensorflow.keras.models import Sequential
> from tensorflow.keras.layers import Dense
> from tensorflow.keras.layers import Dropout
> from tensorflow.keras.layers import Flatten
> from tensorflow.keras.layers import Conv2D
> from tensorflow.keras.layers import MaxPooling2D
> from tensorflow.keras.utils import to_categorical
```

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2. Matplotlib setup, part 1

- First three lines setup the font manager, so that we can display Japanese words correctly in later usage

- Use 'ggplot' style to plot our training and testing result

```
> from matplotlib import font_manager as fm
> fpath       = os.path.join(os.getcwd(), "ipam.ttf")
> prop        = fm.FontProperties(fname=fpath)
```

```
> plt.style.use('ggplot')
> plt.rcParams['ytick.right']      = True
> plt.rcParams['ytick.labelright']= True
> plt.rcParams['ytick.left']       = False
> plt.rcParams['ytick.labelleft'] = False
> plt.rcParams['font.family']      = 'Arial'
```

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2. Matplotlib setup, part 2

- Create a function that can display gray scale image correctly

```
> def grayplt(img,title=''):
      plt.axis('off')
      if np.size(img.shape) == 3:
         plt.imshow(img[:,:,0],cmap='gray',vmin=0,vmax=1)
      else:
         plt.imshow(img,cmap='gray',vmin=0,vmax=1)
      plt.title(title, fontproperties=prop)
      plt.show()
```

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3. Data preparation, part 1

- Load train and test data; load train and test labels

- Rescale data to float, range from 0 to 1

```
> trDat        = np.load('kmnist-train-imgs.npz')['arr_0']
> trLbl        = np.load('kmnist-train-labels.npz')['arr_0']
> tsDat        = np.load('kmnist-test-imgs.npz')['arr_0']
> tsLbl        = np.load('kmnist-test-labels.npz')['arr_0']

> trDat        = trdata.astype('float32')/255
> tsDat        = tsDat.astype('float32')/255

> imgrows      = trDat.shape[1]
> imgclms      = trDat.shape[2]
```

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3. Data preparation, part 2

- The current shape for trDat is `(60000, 28, 28)`
- The current shape for tsDat is `(10000, 28, 28)`
- Need to be reshaped into the form of (samples, width, height, channel)

```
> trDat       = trDat.reshape(trDat.shape[0],
                               imgrows,
                               imgclms,
                               1)
> tsDat       = tsDat.reshape(tsDat.shape[0],
                              imgrows,
                              imgclms,
                              1)
```

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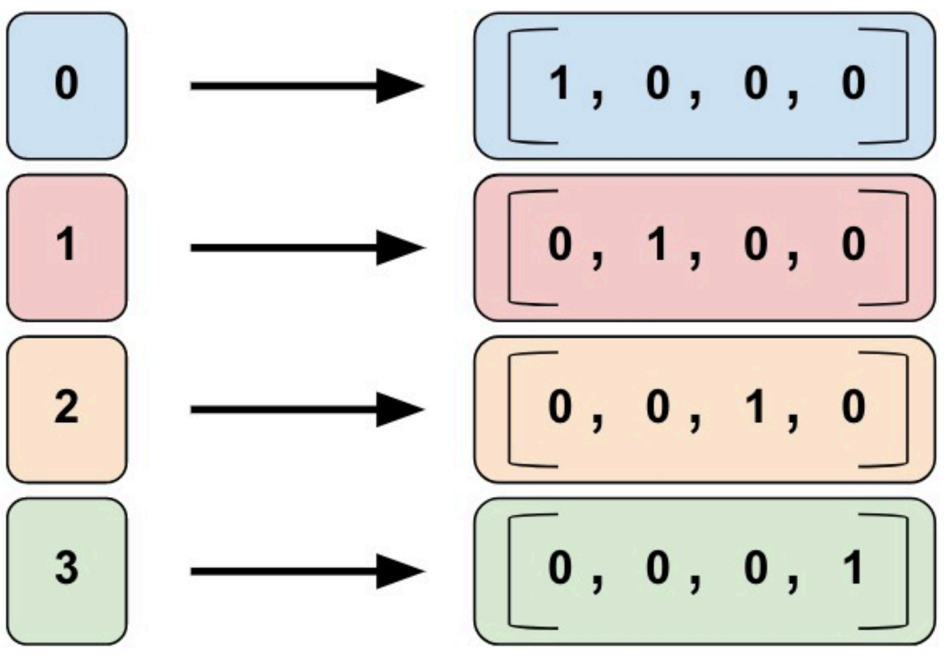
3. Data preparation, part 3

- One-hot encode the train and test label information; get the number of classes in the labels

```
> trLbl       = to_categorical(trlabel)
> tsLbl       = to_categorical(tsLbl)
> num_classes = tsLbl.shape[1]
```



Source: https://arxiv.org/pdf/1812.01718.pdf

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4. Define model, part 1

```
> seed         = 29
> np.random.seed(seed)

> modelname    = 'wks5_1a'
> def createModel():
      model = Sequential()
      model.add(Conv2D(20, (5, 5), input_shape=(28, 28, 1), activation='relu'))
      model.add(MaxPooling2D(pool_size=(2, 2)))
      model.add(Conv2D(40, (5, 5), activation='relu'))
      model.add(MaxPooling2D(pool_size=(2, 2)))
      model.add(Dropout(0.2))
      model.add(Flatten())
      model.add(Dense(128, activation='relu'))
      model.add(Dense(num_classes, activation='softmax'))

      model.compile(loss='categorical_crossentropy', optimizer='adam',
                    metrics=['accuracy'])
      return model
```

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4. Define model, part 2

- 'model' for training; 'modelGo' for final evaluation

```
> model       = createModel()
> modelGo     = createModel()

> model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 24, 24, 20)        520
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 12, 12, 20)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 8, 8, 40)          20040
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 4, 4, 40)          0
_________________________________________________________________
dropout_1 (Dropout)          (None, 4, 4, 40)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 640)               0
_________________________________________________________________
dense_1 (Dense)              (None, 128)               82048
_________________________________________________________________
dense_2 (Dense)              (None, 10)                1290
=================================================================
Total params: 103,898
Trainable params: 103,898
Non-trainable params: 0
_________________________________________________________________
```

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4. Define model, part 3

- Create checkpoints to save model during training and save training data into csv

```
> filepath         = modelname + ".hdf5"
> checkpoint       = ModelCheckpoint(filepath,
                                     monitor='val_acc',
                                     verbose=0,
                                     save_best_only=True,
                                     mode='max')


> csv_logger       = CSVLogger(modelname + '.csv')
> callbacks_list   = [checkpoint,csv_logger]
```

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5. Train model

- Training is only a single line

```
> model.fit(trDat,
            trLbl,
            validation_data=(tsDat, tsLbl),
            epochs=60,
            batch_size=128,
            callbacks=callbacks_list)
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/60
60000/60000 [==============================] - 68s 1ms/sample - loss: 0.4707 - acc: 0.8539 - val_loss: 0.4163 - val_acc: 0.8689
Epoch 2/60
60000/60000 [==============================] - 66s 1ms/sample - loss: 0.1603 - acc: 0.9509 - val_loss: 0.3003 - val_acc: 0.9125
Epoch 3/60
60000/60000 [==============================] - 66s 1ms/sample - loss: 0.1068 - acc: 0.9673 - val_loss: 0.2459 - val_acc: 0.9290
Epoch 4/60
60000/60000 [==============================] - 65s 1ms/sample - loss: 0.0798 - acc: 0.9751 - val_loss: 0.2348 - val_acc: 0.9352
Epoch 5/60
60000/60000 [==============================] - 65s 1ms/sample - loss: 0.0653 - acc: 0.9794 - val_loss: 0.2254 - val_acc: 0.9406
......
```

Kuzushiji MNIST

6. Test model, part 1

- Use a new object to load the weights, and check the best accuracy

```
> modelGo.load_weights(filepath)
> modelGo.compile(loss='categorical_crossentropy',
                  optimizer='adam',
                  metrics=['accuracy'])
```

Kuzushiji MNIST

6. Test model, part 2

- Test the model, calculate the accuracy and confusion matrix

```
> predicts     = modelGo.predict(tsDat)

> predout      = np.argmax(predicts,axis=1)
> testout      = np.argmax(tsLbl,axis=1)
> labelname    = ['お O','き Ki','す Su','つ Tsu','な Na',
                  'は Ha','ま Ma','や Ya','れ Re','を Wo']


> testScores   = metrics.accuracy_score(testout,predout)
> confusion    = metrics.confusion_matrix(testout,predout)
```

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6. Test model, part 3

- Test the model, calculate the accuracy and confusion matrix

```
> print("Best accuracy (on testing dataset): %.2f%%" % (testScores*100))
> print(metrics.classification_report(testout,predout,target_names=labelname,digits=4))
> print(confusion)
```

```
Best accuracy (on testing dataset): 96.56%
             precision    recall  f1-score   support

        お O     0.9615    0.9740    0.9677      1000
       き Ki     0.9772    0.9430    0.9598      1000
       す Su     0.9562    0.9390    0.9475      1000
      つ Tsu     0.9732    0.9820    0.9776      1000
       な Na     0.9588    0.9530    0.9559      1000
       は Ha     0.9707    0.9600    0.9653      1000
       ま Ma     0.9245    0.9920    0.9571      1000
       や Ya     0.9877    0.9620    0.9747      1000
       れ Re     0.9665    0.9800    0.9732      1000
       を Wo     0.9838    0.9710    0.9774      1000

avg / total     0.9660    0.9656    0.9656     10000
```

```
[[974   2   1   1  18   1   0   1   1   1]
 [  5 943   6   0   5   2  24   3   7   5]
 [  8   3 939   9   4   7  19   4   7   0]
 [  0   0   8 982   0   4   5   0   1   0]
 [ 12   2   1   9 953   4   8   2   6   3]
 [  1   3  13   4   1 960  13   0   3   2]
 [  0   2   3   0   1   2 992   0   0   0]
 [  7   5   5   0   5   2   5 962   5   4]
 [  2   1   4   3   5   3   1   0 980   1]
 [  4   4   2   1   2   4   6   2   4 971]]
```

Kuzushiji MNIST

6. Test model, part 4

- Plot the result

```
> import pandas as pd

> records     = pd.read_csv(modelname +'.csv')
> plt.figure()
> plt.subplot(211)
> plt.plot(records['val_loss'])
> plt.yticks([0.00,0.10,0.20,0.30])
> plt.title('Loss value',fontsize=12)

> ax          = plt.gca()
> ax.set_xticklabels([])

> plt.subplot(212)
> plt.plot(records['val_acc'])
> plt.yticks([0.93,0.95,0.97,0.99])
> plt.title('Accuracy',fontsize=12)
> plt.show()
```