

import library

In [1]:

```
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers, models
import numpy as np
import matplotlib.pyplot as plt
```

Get MNIST Data.

MNIST data loacted in tensorflow > keras > datasets > mnist

Split data to (train images, train labels) and (test images, test labels)

In [2]:

```
mnist = keras.datasets.mnist
(train_images, train_labels), (test_images, test_labels) = mnist.load_data()
```

Downloading data from <https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.npz>
11493376/11490434 [=====] - 14s 1us/step

There are Total 60000 Train images and Train labels. (6000 images for single class)

Shape of single image is 28 x 28 (pixel)

In [3]:

```
print('Shape of Train images : ',train_images.shape)
print('Shape of Train labels : ', train_labels.shape)
print('\nShape of Test images : ', test_images.shape)
print("Shape of Test labels : ",test_labels.shape)
```

```
Shape of Train images : (60000, 28, 28)
Shape of Train labels : (60000,)
```

```
Shape of Test images : (10000, 28, 28)
Shape of Test labels : (10000,)
```

In [4]:

```
print('Train labels : ',train_labels)
```

```
Train labels : [5 0 4 ... 5 6 8]
```

Plot first train image.

when value is close to 0 : dark

when value is close to 255 : white

In [5]:

```
print(train_images[1])
```

```
[[ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  51 159 253
 159 50  0  0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  48 238 252 252
 252 237  0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  54 227 253 252 239
 233 252 57  6  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 10  60 224 252 253 252 202
 84 252 253 122  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 163 252 252 252 253 252 252
 96 189 253 167  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 51 238 253 253 190 114 253 228
 47 79 255 168  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 48 238 252 252 179 12 75 121 21
 0  0 253 243 50  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 38 165 253 233 208 84  0  0  0  0
 0  0 253 252 165  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 7 178 252 240 71 19 28  0  0  0  0
 0  0 253 252 195  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 57 252 252 63  0  0  0  0  0  0
 0  0 253 252 195  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 198 253 190  0  0  0  0  0  0  0
 0  0 255 253 196  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 76 246 252 112  0  0  0  0  0  0  0
 0  0 253 252 148  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 85 252 230 25  0  0  0  0  0  0  0
 7 135 253 186 12  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 85 252 223  0  0  0  0  0  0  0  7
 131 252 225 71  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 85 252 145  0  0  0  0  0  0  0 48 165
 252 173  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 86 253 225  0  0  0  0  0  0 114 238 253
 162  0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 85 252 249 146 48 29 85 178 225 253 223 167
 56  0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 85 252 252 252 229 215 252 252 252 196 130  0
 0  0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 28 199 252 252 253 252 252 233 145  0  0  0
 0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 25 128 252 253 252 141 37  0  0  0  0
 0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0]]
```

Plot First 10 Train images and Corresponding labels

In [6]:

```
print('First 10 Train images in MNIST dataset\n')
for i in range(10):
    plt.subplot(1, 10, i+1)
    plt.xticks([])
    plt.yticks([])
    plt.imshow(train_images[i])
plt.show()
```

```
print('\nTrain labels match with Train label sequentially\n',train_labels[:10])
```

First 10 Train images in MNIST dataset



Train labels match with Train label sequentially
[5 0 4 1 9 2 1 3 1 4]

Important

Change data shape (60000 x 28 x 28) to (60000 x 28 x 28 x 1)

In [7]:

```
train_images = tf.reshape(train_images, [-1, 28, 28, 1])  
test_images = tf.reshape(test_images, [-1, 28, 28, 1])
```

Select one convolution model below

There are 3 example models.

3, 5, 7 layer each

MODEL 1 : 3 Layers with 1 Convolution layer

MODEL 2 : 5 Layers with 2 Convolution layer

MODEL 3 : 7 Layers with 4 Convolution layer

In [8]:

```
def select_model(model_number):  
    if model_number == 1:  
        model = keras.models.Sequential([  
            keras.layers.Conv2D(32, (3,3), activation = 'relu', input_shape = (28, 28,1)), # layer 1  
            keras.layers.MaxPool2D((2,2)),  
            # layer 2  
            keras.layers.Flatten(),  
            keras.layers.Dense(10, activation = 'softmax')])  
        # layer 3  
  
    if model_number == 2:  
        model = keras.models.Sequential([  
            keras.layers.Conv2D(32, (3,3), activation = 'relu', input_shape=(28, 28,1)), # layer 1  
            keras.layers.MaxPool2D((2,2)),  
            # layer 2  
            keras.layers.Conv2D(64, (3,3), activation = 'relu'),  
            # layer 3  
            keras.layers.MaxPool2D((2,2)),  
            # layer 4  
            keras.layers.Flatten(),  
            keras.layers.Dense(10, activation = 'softmax')])  
        # layer 5  
  
    if model_number == 3:  
        model = keras.models.Sequential([  
            keras.layers.Conv2D(32, (3,3), activation = 'relu', input_shape = (28, 28,1)), # layer 1  
            keras.layers.MaxPool2D((2,2)),  
            # layer 2  
            keras.layers.Conv2D(64, (3,3), activation = 'relu'),  
            # layer 3  
            keras.layers.MaxPool2D((2,2)),  
            # layer 4  
            keras.layers.Flatten(),  
            keras.layers.Dense(10, activation = 'softmax')])  
        # layer 5  
        # layer 6  
        # layer 7
```

```

8, 28,1)), # layer 1
keras.layers.MaxPool2D((2,2)),
# layer 2
keras.layers.Conv2D(64, (3,3), activation = 'relu'),
# layer 3
keras.layers.Conv2D(64, (3,3), activation = 'relu'),
# layer 4
keras.layers.MaxPool2D((2,2)),
# layer 5
keras.layers.Conv2D(128, (3,3), activation = 'relu'),
# layer 6
keras.layers.Flatten(),
keras.layers.Dense(10, activation = 'softmax'])

return model

```

In [9]:

```
model = select_model(1)
```

If you want to see information of model, model.summary() will help

summary() is also built in function

In [10]:

```
model.summary()
```

Model: "sequential"

| Layer (type) | Output Shape | Param # |
|------------------------------|--------------------|---------|
| conv2d (Conv2D) | (None, 26, 26, 32) | 320 |
| max_pooling2d (MaxPooling2D) | (None, 13, 13, 32) | 0 |
| flatten (Flatten) | (None, 5408) | 0 |
| dense (Dense) | (None, 10) | 54090 |
| Total params: 54,410 | | |
| Trainable params: 54,410 | | |
| Non-trainable params: 0 | | |

Components in training step

Optimizer, Loss function, accuracy metrics

In [11]:

```

model.compile(
    optimizer = 'adam',
    loss = 'sparse_categorical_crossentropy',
    metrics = ['accuracy']
)

```

Training Step

Training for 5 epochs.

In [12]:

```
model.fit(train_images, train_labels, epochs = 5)
```

Train on 60000 samples

Epoch 1/5

60000/60000 [=====] - 26s 430us/sample - loss: 0.7654 - accuracy : 0.9409

Epoch 2/5

60000/60000 [=====] - 23s 383us/sample - loss: 0.0828 - accuracy : 0.9754

Epoch 3/5

60000/60000 [=====] - 21s 342us/sample - loss: 0.0703 - accuracy : 0.9786

Epoch 4/5

60000/60000 [=====] - 26s 433us/sample - loss: 0.0606 - accuracy : 0.9811- loss: 0.0589 - - ETA - ETA

Epoch 5/5

60000/60000 [=====] - 25s 419us/sample - loss: 0.0521 - accuracy : 0.9843

Out[12]:

<tensorflow.python.keras.callbacks.History at 0x1feb6810828>

Test Step

Perform Test with Test data

In [13]:

```
test_loss, accuracy = model.evaluate(test_images, test_labels, verbose = 2)
print('\nTest loss : ', test_loss)
print('Test accuracy : ', accuracy)
```

10000/1 - 1s - loss: 0.1879 - accuracy: 0.9759

Test loss : 0.1162389629466401

Test accuracy : 0.9759

Before prediction, change test image's type to float 32.

In [14]:

```
test_images = tf.cast(test_images, tf.float32)
pred = model.predict(test_images)
Number = [0,1,2,3,4,5,6,7,8,9]
```

In [15]:

```
print('Prediction : ', pred.shape)
print('Test labels : ', test_labels.shape)
```

Prediction : (10000, 10)

Test labels : (10000,)

Functions for plot images, probability

In [16]:

```
def plot_image(i, predictions_array, true_label, img):
    predictions_array, true_label, img = predictions_array[i], true_label[i], img[i]
    plt.grid(False)
    plt.xticks([])
    plt.yticks([])

    plt.imshow(img, cmap=plt.cm.binary)
```

```

predicted_label = np.argmax(predictions_array)
if predicted_label == true_label:
    color = 'blue'
else:
    color = 'red'

plt.xlabel("{} {:.20f}% {}".format(Number[predicted_label],
                                   100*np.max(predictions_array),
                                   Number[true_label]),
          color=color)

def plot_value_array(i, predictions_array, true_label):
    predictions_array, true_label = predictions_array[i], true_label[i]
    plt.grid(False)
    plt.xticks([])
    plt.yticks([])
    thisplot = plt.bar(range(10), predictions_array, color="#777777")
    plt.ylim([0, 1])
    predicted_label = np.argmax(predictions_array)
    plt.xticks(Number)

    thisplot[predicted_label].set_color('red')
    thisplot[true_label].set_color('blue')

```

In [17]:

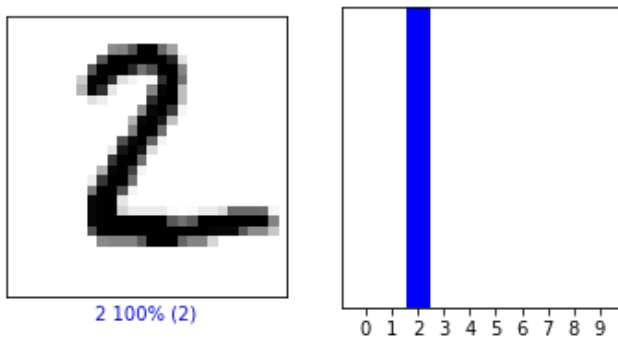
```
(train_images, train_labels), (test_images, test_labels) = mnist.load_data()
```

In [18]:

```

i = 1
plt.figure(figsize=(6,3))
plt.subplot(1,2,1)
plot_image(i, pred, test_labels, test_images)
plt.subplot(1,2,2)
plot_value_array(i, pred, test_labels)
plt.show()

```

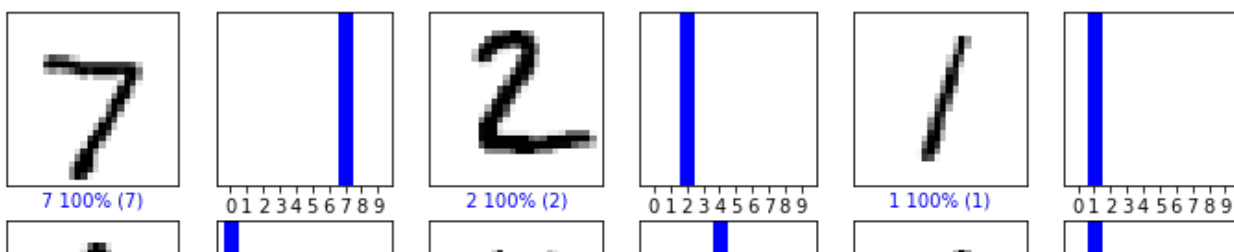


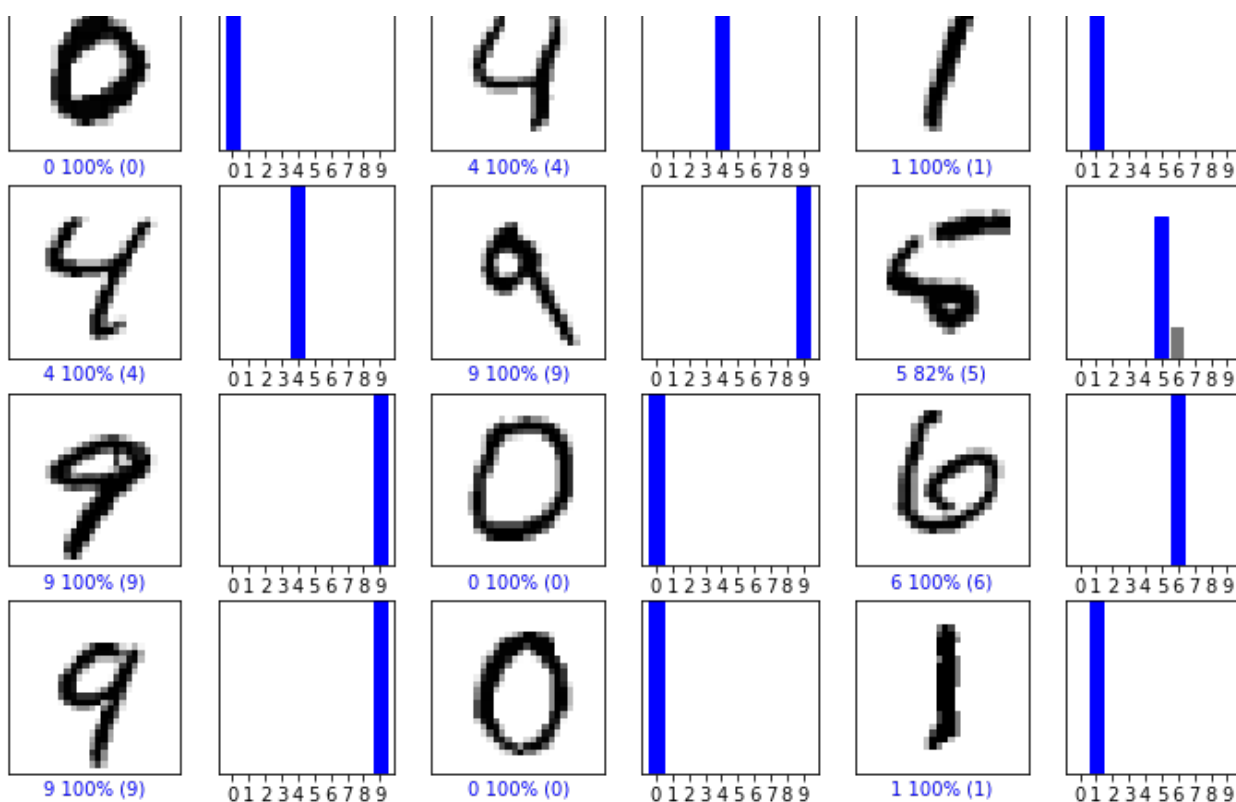
In [19]:

```

num_rows = 5
num_cols = 3
num_images = num_rows*num_cols
plt.figure(figsize=(2*2*num_cols, 2*num_rows))
for i in range(num_images):
    plt.subplot(num_rows, 2*num_cols, 2*i+1)
    plot_image(i, pred, test_labels, test_images)
    plt.subplot(num_rows, 2*num_cols, 2*i+2)
    plot_value_array(i, pred, test_labels)
plt.show()

```





Plot images and probability that model predicted wrong

In [20]:

```
def error_mnist(prediction_array, true_label):
    error_index = []

    for i in range(true_label.shape[0]):
        if np.argmax(prediction_array[i]) != true_label[i]:
            error_index.append(i)
    return error_index

# change num_cols, num_rows if you want to see more result.
def plot_error(index, prediction_array, true_label):
    num_cols = 5
    num_rows = 5
    plt.figure(figsize=(2*2*num_cols, 2*num_rows))

    assert len(index) < num_cols * num_rows
    for i in range(len(index)):
        plt.subplot(num_rows, 2*num_cols, 2*i+1)
        idx = index[i]
        plt.imshow(test_images[idx])
        plt.subplot(num_rows, 2*num_cols, 2*i+2)
        plt.bar(range(10), prediction_array[idx])
        plt.xticks(Numbers)
```

Find index of wrong prediction

Plot first 10 wrong predicted images and probability

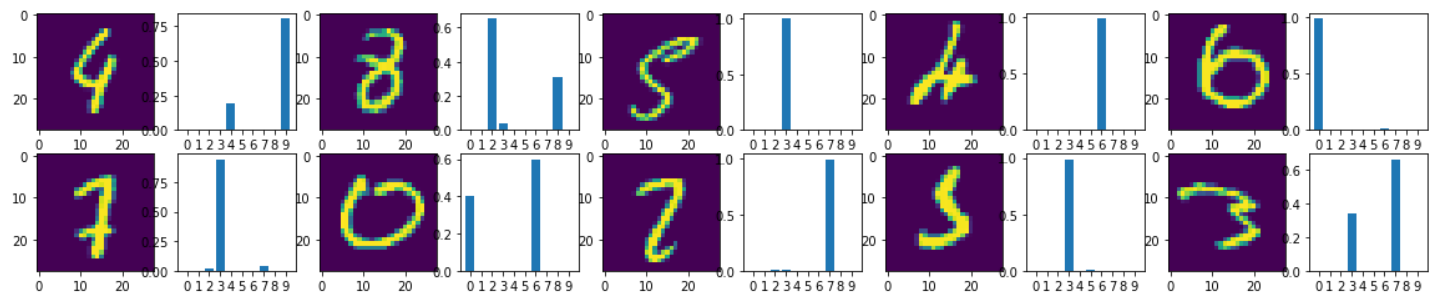
In [21]:

```
index = error_mnist(pred, test_labels)
index_slice = index[:10]
print(index[:10])
```

[115, 184, 211, 247, 259, 282, 297, 321, 340, 381]

In [22]:

```
plot_error(index_slice, pred, test_labels)
```



In [23]:

DONE

```
-----  
NameError                                Traceback (most recent call last)  
<ipython-input-23-87f6c984fac4> in <module>  
----> 1 DONE
```

NameError: name 'DONE' is not defined