Fashion-MNIST Wei Pan

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Reference for this script: https://github.com/ageron/handson-ml https://gist.github.com/hitvoice/36cf44689065ca9b927431546381a3f7/In Fashion MNIST dataset, each training and test example is assigned to one of the following labels:

0 T-shirt/top 1 Trouser 2 Pullover 3 Dress 4 Coat 5 Sandal 6 Shirt 7 Sneaker 8 Bag 9 Ankle boot

0.1 Setup

```
In [1]: # To support both python 2 and python 3
        from __future__ import division, print_function, unicode_literals

        # Common imports
        import numpy as np
        import pandas as pd
        import os
        import warnings
        warnings.filterwarnings("ignore")

        import tensorflow as tf
        from tensorflow import keras
        from tensorflow_graph_in_jupyter import show_graph

        from sklearn.model_selection import cross_val_score
        from sklearn.model_selection import cross_val_predict
        from sklearn.metrics import precision_score, recall_score
        from sklearn.metrics import confusion_matrix

        # to make this notebook's output stable across runs
        np.random.seed(42)

        # To plot pretty figures
        import seaborn as sns
        %matplotlib inline
        import matplotlib
        import matplotlib.pyplot as plt
        plt.rcParams['axes.labelsize'] = 14
        plt.rcParams['xtick.labelsize'] = 12
        plt.rcParams['ytick.labelsize'] = 12
        # Where to save the figures
        PROJECT_ROOT_DIR = "."

        def save_fig(fig_id, tight_layout=True):
            path = os.path.join(PROJECT_ROOT_DIR, fig_id + ".png")
            print("Saving figure", fig_id)
            if tight_layout:
                plt.tight_layout()
            plt.savefig(path, format='png', dpi=600)
```

```
In [2]:  print(tf.__version__)
```

```
1.13.0-rc2
```

```
In [3]: # To plot images
        def plot_images(instances, images_per_row=10, **options):
            size = 28
            images_per_row = min(len(instances), images_per_row)
            images = [instance.reshape(size,size) for instance in instances]
            n_rows = (len(instances) - 1) // images_per_row + 1
            row_images = []
            n_empty = n_rows * images_per_row - len(instances)
            images.append(np.zeros((size, size * n_empty)))
            for row in range(n_rows):
                rimages = images[row * images_per_row : (row + 1) * images_per_row]
                row_images.append(np.concatenate(rimages, axis=1))
            image = np.concatenate(row_images, axis=0)
            plt.imshow(image, cmap = matplotlib.cm.binary, **options)
            plt.axis("off")
```

```
In [4]: # To plot confusion matrix
        # Source: https://gist.github.com/hitvoice/36cf44689065ca9b927431546381a3f7/
        def confusion_matrix_plot(y_true, y_pred, filename, labels= range(10), ymap=None, figs
                                  midpoint=500,color=None, v_min=0,v_max=1000):
            if ymap is not None:
                y_pred = [ymap[yi] for yi in y_pred]
                y_true = [ymap[yi] for yi in y_true]
                labels = [ymap[yi] for yi in labels]
            cm = confusion_matrix(y_true, y_pred, labels=labels)
            cm_sum = np.sum(cm, axis=1, keepdims=True)
            cm_perc = cm / cm_sum.astype(float) * 100
            annot = np.empty_like(cm).astype(str)
            nrows, ncols = cm.shape
            for i in range(nrows):
                for j in range(ncols):
                    c = cm[i, j]
                    p = cm_perc[i, j]
                    if i == j:
```

```
                s = cm_sum[i]
                annot[i, j] = '%.1f%%\n%d/%d' % (p, c, s)
            elif c == 0:
                annot[i, j] = ''
            else:
                annot[i, j] = '%.1f%%\n%d' % (p, c)
    cm = pd.DataFrame(cm, index=labels, columns=labels)
    cm.index.name = 'Actual'
    cm.columns.name = 'Predicted'
    fig, ax = plt.subplots(figsize=figsize)
    sns.heatmap(cm, annot=annot, fmt='', ax=ax, annot_kws={"size": 13},
                cmap=color, center=midpoint, vmin=v_min, vmax=v_max)
    plt.savefig(filename)
```

0.2 Get the Data

```
In [5]: # import data
        zalando_data_train = pd.read_csv('fashion-mnist_train.csv')
        zalando_data_test = pd.read_csv('fashion-mnist_test.csv')
```

```
In [6]: y_train_raw = zalando_data_train['label'].values
        print(y_train_raw.shape)
        X_train_raw = zalando_data_train.drop('label', axis=1).values
        print(X_train_raw.shape)
        y_test_raw = zalando_data_test['label'].values
        print(y_test_raw.shape)
        X_test_raw = zalando_data_test.drop('label', axis=1).values
        print(X_test_raw.shape)
```

```
(60000,)
(60000, 784)
(10000,)
(10000, 784)
```

```
In [7]: print (zalando_data_train['label'].value_counts())
```

```
9    6000
8    6000
7    6000
6    6000
5    6000
4    6000
3    6000
2    6000
1    6000
0    6000
Name: label, dtype: int64
```

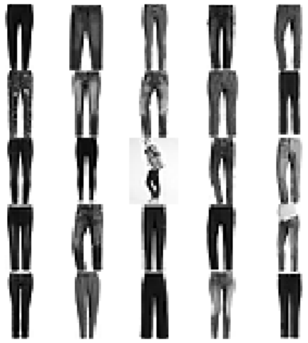
```
In [8]: # show some images
        plt.figure(figsize=(9,9))
        example_images = np.r_[X_train_raw[:12000:600], X_train_raw[13000:30600:600], X_train_
        plot_images(example_images, images_per_row=10)
        save_fig("images_plot")
        plt.show()
```

```
Saving figure images_plot
```

```
In [9]: # plot images for each label
        X_0 = X_train_raw[(y_train_raw == 0)]
        X_1 = X_train_raw[(y_train_raw == 1)]
        X_2 = X_train_raw[(y_train_raw == 2)]
```

```
X_3 = X_train_raw[(y_train_raw == 3)]
X_4 = X_train_raw[(y_train_raw == 4)]
X_5 = X_train_raw[(y_train_raw == 5)]
X_6 = X_train_raw[(y_train_raw == 6)]
X_7 = X_train_raw[(y_train_raw == 7)]
X_8 = X_train_raw[(y_train_raw == 8)]
X_9 = X_train_raw[(y_train_raw == 9)]

plt.figure(figsize=(24,24))
plt.subplot(521); plot_images(X_0[:25], images_per_row=5)
plt.subplot(522); plot_images(X_1[:25], images_per_row=5)
plt.subplot(523); plot_images(X_2[:25], images_per_row=5)
plt.subplot(524); plot_images(X_3[:25], images_per_row=5)
plt.subplot(525); plot_images(X_4[:25], images_per_row=5)
plt.subplot(526); plot_images(X_5[:25], images_per_row=5)
plt.subplot(527); plot_images(X_6[:25], images_per_row=5)
plt.subplot(528); plot_images(X_7[:25], images_per_row=5)
plt.subplot(529); plot_images(X_8[:25], images_per_row=5)
plt.subplot(5,2,10); plot_images(X_9[:25], images_per_row=5)
save_fig("images_for_each_label")
plt.show()
```

```
Saving figure images_for_each_label
```



0.3 Linear Classifier

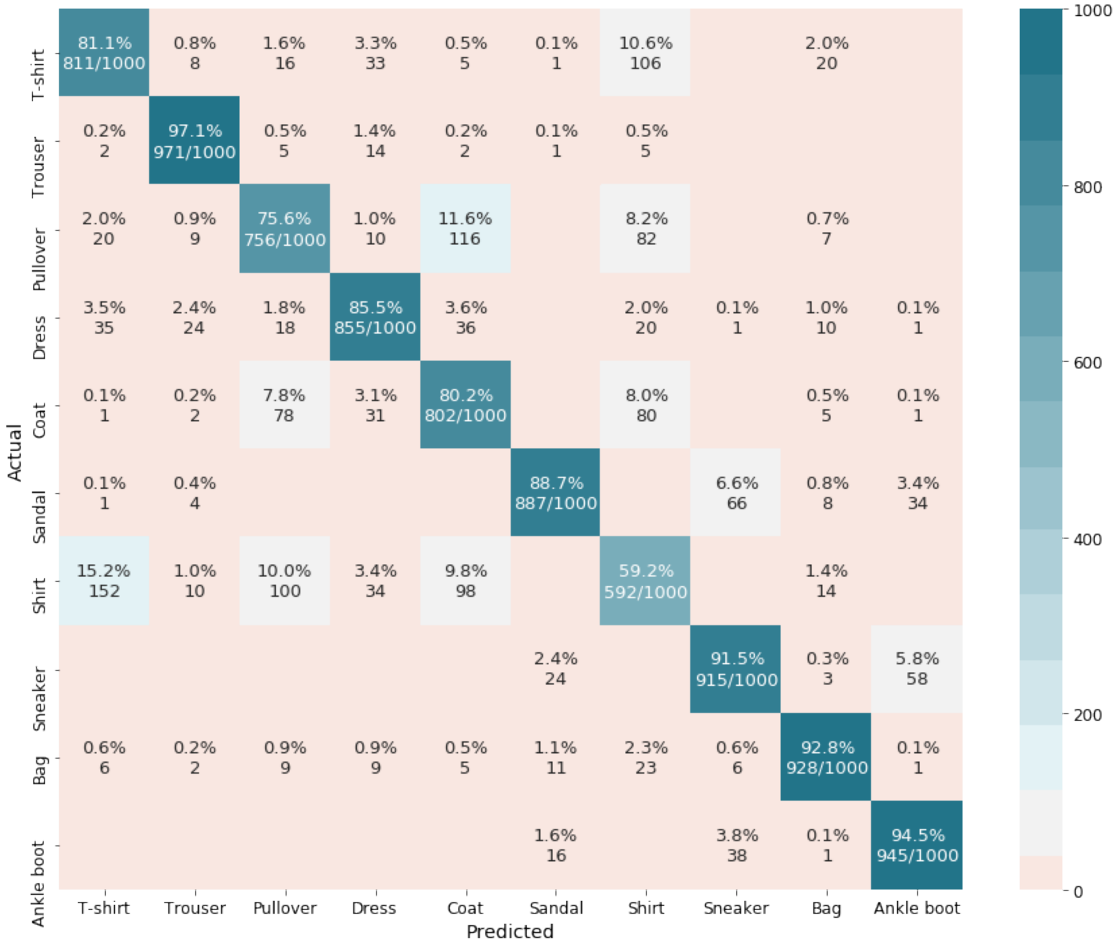
```
In [10]: # prepare data
         y_train = y_train_raw
         X_train = X_train_raw
         y_test = y_test_raw
         X_test = X_test_raw
```

```
In [11]: # prepare Logistic Regression classifier
         from sklearn.linear_model import LogisticRegression
         logit_clf = LogisticRegression(tol=0.0001, C=1.0, random_state=42, solver='sag',
                                        max_iter=300, multi_class='multinomial')
```

```
In [12]: # training and validation
         logit_clf.fit(X_train, y_train)
         y_train_logit_pred = logit_clf.predict(X_train)
         y_test_logit_pred = logit_clf.predict(X_test)

         print("Training Accuracy",(y_train_logit_pred  == y_train).mean())
         print("Test Accuracy",(y_test_logit_pred  == y_test).mean())
```

```
/anaconda3/lib/python3.6/site-packages/sklearn/linear_model/sag.py:334: ConvergenceWarning: The
  "the coef_ did not converge", ConvergenceWarning)


Training Accuracy 0.8794166666666666
Test Accuracy 0.8462
```

```
In [13]: # Evaluating classifier
         confusion_matrix_plot(y_test, y_test_logit_pred,
             filename="confusion_matrix_logit_test",
             ymap={0:"T-shirt", 1:"Trouser", 2:"Pullover",3:"Dress",4:"Coat",5:"Sandal",
             6:"Shirt",7:"Sneaker",8:"Bag",9:"Ankle boot"},
             color=sns.diverging_palette(20,220, sep=10, n=25, s=90, l=45,center ='light'),
             midpoint=75,figsize=(15,12),v_min=0,v_max=1000)
```

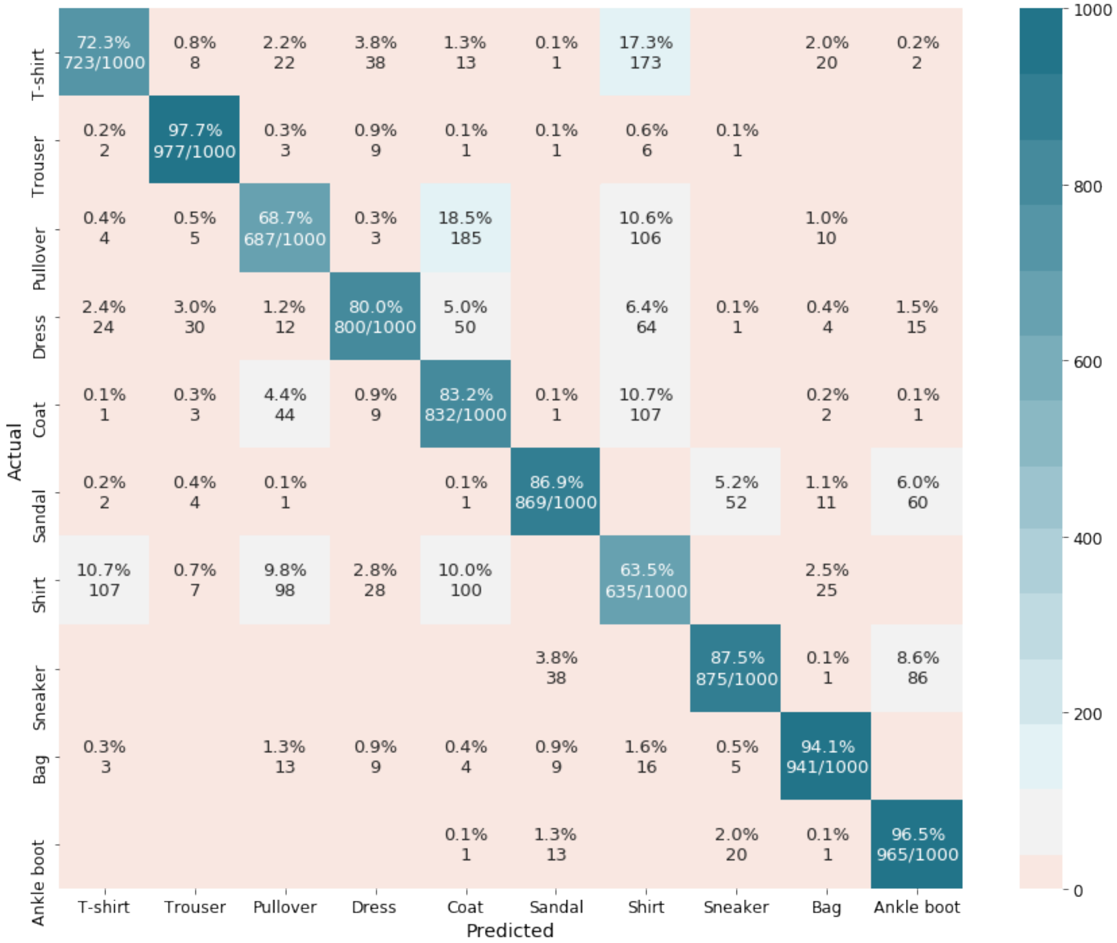


```
In [14]: # Linear SVM classfier
         from sklearn.linear_model import SGDClassifier
         sgd_svm_clf = SGDClassifier(max_iter=150, random_state=42,loss='hinge', tol=0.01)
         sgd_svm_clf.fit(X_train, y_train)

/anaconda3/lib/python3.6/site-packages/sklearn/linear_model/stochastic_gradient.py:603: Conver
  ConvergenceWarning)


Out[14]: SGDClassifier(alpha=0.0001, average=False, class_weight=None,
                early_stopping=False, epsilon=0.1, eta0=0.0, fit_intercept=True,
                l1_ratio=0.15, learning_rate='optimal', loss='hinge', max_iter=150,
                n_iter=None, n_iter_no_change=5, n_jobs=None, penalty='l2',
                power_t=0.5, random_state=42, shuffle=True, tol=0.01,
                validation_fraction=0.1, verbose=0, warm_start=False)

In [15]: # training and validation
         y_train_sgd_svm_pred = sgd_svm_clf.predict(X_train)
```

```
        y_test_sgd_svm_pred = sgd_svm_clf.predict(X_test)

        print("Training Accuracy",(y_train_sgd_svm_pred == y_train).mean())
        print("Test Accuracy",(y_test_sgd_svm_pred == y_test).mean())
```

```
Training Accuracy 0.8507833333333333
Test Accuracy 0.8304
```

```
In [16]: # Evaluating classifier
         confusion_matrix_plot(y_test, y_test_sgd_svm_pred,
             filename="confusion_matrix_sgd_svm_test",
             ymap={0:"T-shirt", 1:"Trouser", 2:"Pullover",3:"Dress",4:"Coat",5:"Sandal",
             6:"Shirt",7:"Sneaker",8:"Bag",9:"Ankle boot"},
             color=sns.diverging_palette(20,220, sep=10, n=25, s=90, l=45,center ='light'),
             midpoint=75,figsize=(15,12),v_min=0,v_max=1000)
```



0.3.1 Linear SVM Classifier (pre-processing: scaling)

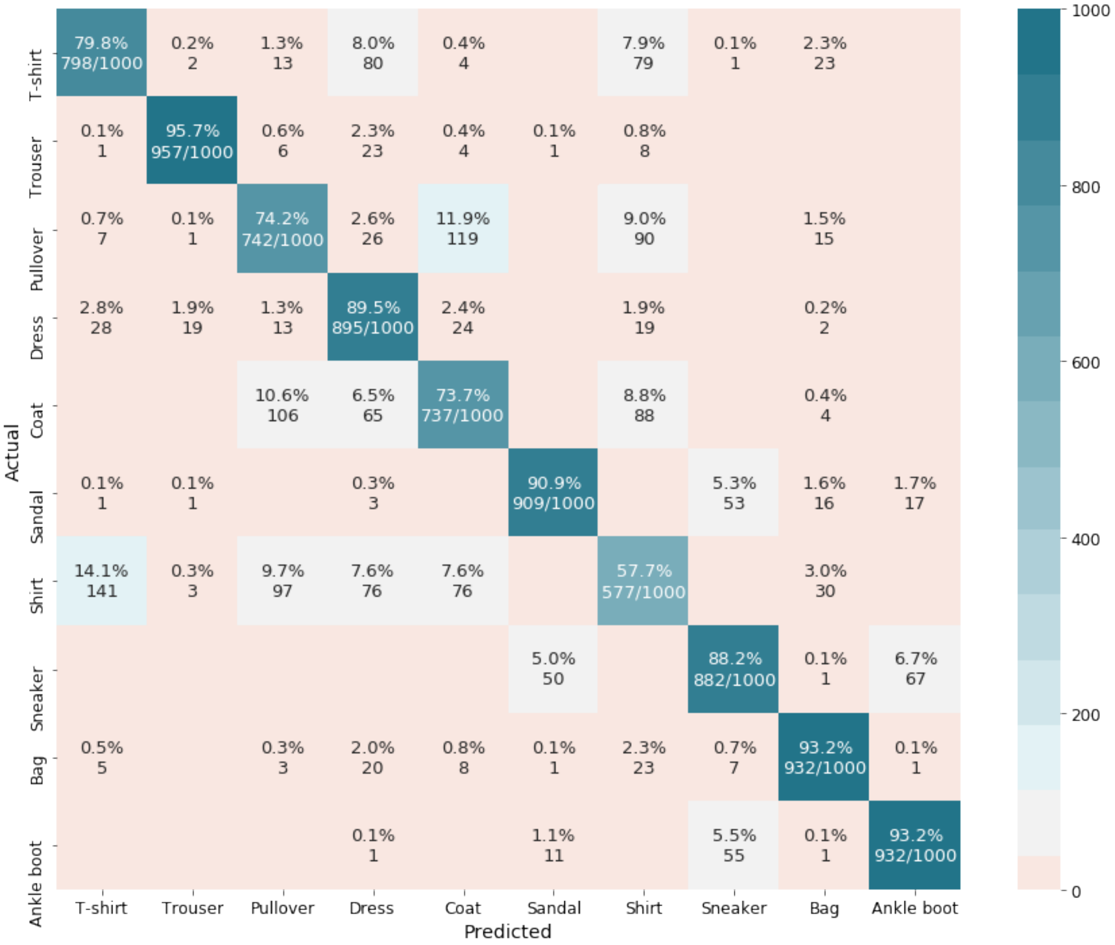
```
In [17]: # prepare classifier
         from sklearn.preprocessing import StandardScaler
         scaler = StandardScaler()
         X_train_scaled = scaler.fit_transform(X_train.astype(np.float64))
         X_test_scaled = scaler.fit_transform(X_test.astype(np.float64))
```

```
In [18]: # training and validation
         sgd_svm_clf = SGDClassifier(max_iter=150, random_state=42,loss='hinge', tol=0.0001)
         sgd_svm_clf.fit(X_train_scaled, y_train)
         y_train_svm_scaled_pred = sgd_svm_clf.predict(X_train_scaled)
         y_test_svm_scaled_pred = sgd_svm_clf.predict(X_test_scaled)

         print("Training Accuracy",(y_train_svm_scaled_pred == y_train).mean())
         print("Test Accuracy",(y_test_svm_scaled_pred == y_test).mean())
```

```
Training Accuracy 0.8434833333333334
Test Accuracy 0.8361
```

```
/anaconda3/lib/python3.6/site-packages/sklearn/linear_model/stochastic_gradient.py:603: Converg
  ConvergenceWarning)
```

```
In [19]: # Evaluating classifier
         confusion_matrix_plot(y_test, y_test_svm_scaled_pred,
             filename="confusion_matrix_sgd_scaled_test",
             ymap={0:"T-shirt", 1:"Trouser", 2:"Pullover",3:"Dress",4:"Coat",5:"Sandal",
             6:"Shirt",7:"Sneaker",8:"Bag",9:"Ankle boot"},
             color=sns.diverging_palette(20,220, sep=10, n=25, s=90, l=45,center ='light'),
             midpoint=75,figsize=(15,12),v_min=0,v_max=1000)
```



0.4 Random Forest Classifier

```
In [42]: # Data preparation
         y_train = y_train_raw
         X_train = X_train_raw
         y_test = y_test_raw
         X_test = X_test_raw
```

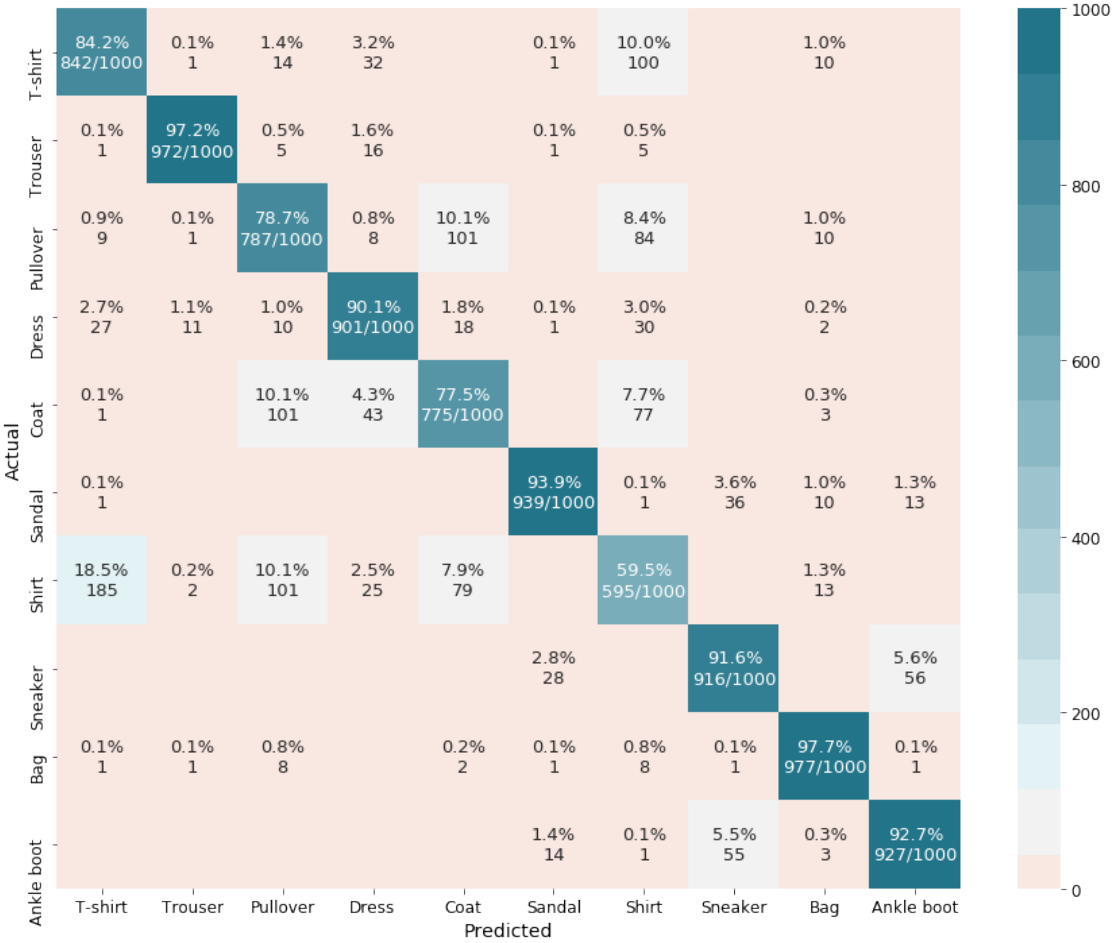
```
In [21]: # Classifier preparation
         from sklearn.ensemble import RandomForestClassifier
         from sklearn.multiclass import OneVsOneClassifier

         # ovo_clf = OneVsOneClassifier(RandomForestClassifier(random_state=42)) # overfitting
         ovo_rf_clf = OneVsOneClassifier(RandomForestClassifier(random_state=42, max_depth = 2
```

```
In [22]: # Training and validation
         ovo_rf_clf.fit(X_train, y_train)
         y_train_rf_pred = ovo_rf_clf.predict(X_train)
```

```
        y_test_rf_pred = ovo_rf_clf.predict(X_test)

        print("Training Accuracy",(y_train_rf_pred == y_train).mean())
        print("Test Accuracy",(y_test_rf_pred == y_test).mean())
```

```
Training Accuracy 0.9906666666666667
Test Accuracy 0.8631
```

```
In [23]: # Evaluating classifier
         confusion_matrix_plot(y_test, y_test_rf_pred,
             filename="confusion_matrix_rf_test",
             ymap={0:"T-shirt", 1:"Trouser", 2:"Pullover",3:"Dress",4:"Coat",5:"Sandal",
             6:"Shirt",7:"Sneaker",8:"Bag",9:"Ankle boot"},
             color=sns.diverging_palette(20,220, sep=10, n=25, s=90, l=45,center ='light'),
             midpoint=75,figsize=(15,12),v_min=0,v_max=1000)
```



0.5 CNN

```
In [25]: def reset_graph(seed=42):
             tf.reset_default_graph()
             tf.set_random_seed(seed)
             np.random.seed(seed)
```

```
In [26]: from datetime import datetime

         now = datetime.utcnow().strftime("%Y%m%d%H%M%S")
         root_logdir = "."
         logdir = "{}//run-{}//".format(root_logdir, now)
```

```
In [ ]: # Building CNN architecture
        height = 28
        width = 28
        channels = 1
        n_inputs = height * width

        conv1_fmaps = 64#16
        conv1_ksize = 3
        conv1_stride = 1
        conv1_pad = "SAME"

        conv2_fmaps = 16
        conv2_ksize = 3
        conv2_stride = 2
        conv2_pad = "SAME"

        pool3_fmaps = 16#8

        n_fc1 = 64#32
        n_outputs = 10

        reset_graph()

        with tf.name_scope("inputs"):
            X = tf.placeholder(tf.float32, shape=[None, n_inputs], name="X")
            X_reshaped = tf.reshape(X, shape=[-1, height, width, channels])
            y = tf.placeholder(tf.int32, shape=[None], name="y")

        conv1 = tf.layers.conv2d(X_reshaped, filters=conv1_fmaps, kernel_size=conv1_ksize,
                                 strides=conv1_stride, padding=conv1_pad,
                                 activation=tf.nn.relu, name="conv1")
        conv2 = tf.layers.conv2d(conv1, filters=conv2_fmaps, kernel_size=conv2_ksize,
                                 strides=conv2_stride, padding=conv2_pad,
                                 activation=tf.nn.relu, name="conv2")

        with tf.name_scope("pool3"):
            pool3 = tf.nn.max_pool(conv2, ksize=[1, 2, 2, 1], strides=[1, 2, 2, 1], padding="V
            pool3_flat = tf.reshape(pool3, shape=[-1, pool3_fmaps * 7 * 7])

        with tf.name_scope("fc1"):
            fc1 = tf.layers.dense(pool3_flat, n_fc1, activation=tf.nn.relu, name="fc1")

        with tf.name_scope("output"):
            logits = tf.layers.dense(fc1, n_outputs, name="output")
            Y_proba = tf.nn.softmax(logits, name="Y_proba")

        with tf.name_scope("train"):
            xentropy = tf.nn.sparse_softmax_cross_entropy_with_logits(logits=logits, labels=y)
            loss = tf.reduce_mean(xentropy)
            optimizer = tf.train.AdamOptimizer()
            training_op = optimizer.minimize(loss)

        with tf.name_scope("eval"):
            correct = tf.nn.in_top_k(logits, y, 1)
            accuracy = tf.reduce_mean(tf.cast(correct, tf.float32))

        with tf.name_scope("init_and_save"):
            init = tf.global_variables_initializer()
            saver = tf.train.Saver()

        file_writer = tf.summary.FileWriter(logdir , tf.get_default_graph())  # for TensorBoar
```

```
In [28]: # Data preparation
         X_train = X_train_raw.astype(np.float32).reshape(-1, 28*28) / 255.0
         X_test = X_test_raw.astype(np.float32).reshape(-1, 28*28) / 255.0
         y_train = y_train_raw.astype(np.int32)
         y_test = y_test_raw.astype(np.int32)
         X_valid, X_train = X_train[:5000], X_train[5000:]
         y_valid, y_train = y_train[:5000], y_train[5000:]
         X_train.shape
```

```
Out[28]: (55000, 784)
```

```
In [29]: def shuffle_batch(X, y, batch_size):
             rnd_idx = np.random.permutation(len(X))
             n_batches = len(X) // batch_size
             for batch_idx in np.array_split(rnd_idx, n_batches):
                 X_batch, y_batch = X[batch_idx], y[batch_idx]
                 yield X_batch, y_batch
```

```
In [30]: # Trainning CNN model
         n_epochs = 30
         batch_size = 100

         with tf.Session() as sess:
             init.run()
             for epoch in range(n_epochs):
                 for X_batch, y_batch in shuffle_batch(X_train, y_train, batch_size):
                     sess.run(training_op, feed_dict={X: X_batch, y: y_batch})
                 acc_batch = accuracy.eval(feed_dict={X: X_batch, y: y_batch})
                 acc_test = accuracy.eval(feed_dict={X: X_test, y: y_test})
                 print(epoch, "Last batch accuracy:", acc_batch, "Test accuracy:", acc_test)
             saver.save(sess, "./fashion_mnist_cnn_model.ckpt")

         file_writer.close() # for TensorBoard
```

```
0 Last batch accuracy: 0.77 Test accuracy: 0.8679
1 Last batch accuracy: 0.91 Test accuracy: 0.8842
2 Last batch accuracy: 0.87 Test accuracy: 0.8985
3 Last batch accuracy: 0.9 Test accuracy: 0.8928
4 Last batch accuracy: 0.95 Test accuracy: 0.9063
5 Last batch accuracy: 0.96 Test accuracy: 0.9054
6 Last batch accuracy: 0.95 Test accuracy: 0.9095
7 Last batch accuracy: 0.92 Test accuracy: 0.9142
8 Last batch accuracy: 0.95 Test accuracy: 0.9168
9 Last batch accuracy: 0.93 Test accuracy: 0.9149
10 Last batch accuracy: 0.98 Test accuracy: 0.9166
11 Last batch accuracy: 0.94 Test accuracy: 0.9168
12 Last batch accuracy: 0.98 Test accuracy: 0.9158
13 Last batch accuracy: 0.94 Test accuracy: 0.9126
14 Last batch accuracy: 0.98 Test accuracy: 0.9143
15 Last batch accuracy: 0.97 Test accuracy: 0.9114
16 Last batch accuracy: 0.93 Test accuracy: 0.9174
17 Last batch accuracy: 0.93 Test accuracy: 0.9182
18 Last batch accuracy: 0.93 Test accuracy: 0.9194
19 Last batch accuracy: 0.93 Test accuracy: 0.9173
20 Last batch accuracy: 0.92 Test accuracy: 0.9138
21 Last batch accuracy: 0.98 Test accuracy: 0.9158
22 Last batch accuracy: 0.99 Test accuracy: 0.9118
23 Last batch accuracy: 0.95 Test accuracy: 0.9164
24 Last batch accuracy: 0.97 Test accuracy: 0.9113
25 Last batch accuracy: 0.94 Test accuracy: 0.9068
26 Last batch accuracy: 0.95 Test accuracy: 0.9141
27 Last batch accuracy: 0.95 Test accuracy: 0.9123
28 Last batch accuracy: 0.98 Test accuracy: 0.9144
29 Last batch accuracy: 1.0 Test accuracy: 0.9133
```

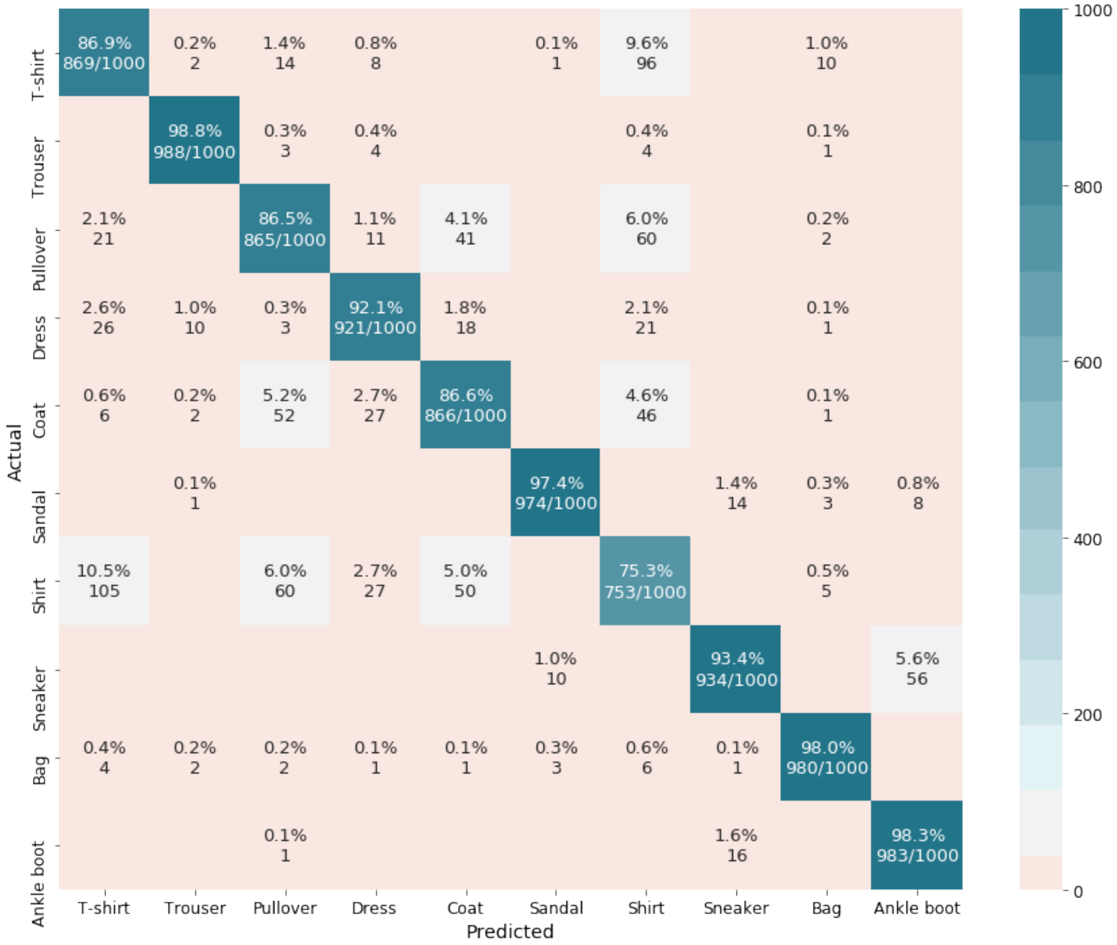
```
In [31]: from tensorflow_graph_in_jupyter import show_graph
         show_graph(tf.get_default_graph())
```

```
<IPython.core.display.HTML object>
```

```
In [32]: # Validation on test set
         with tf.Session() as sess:
             saver.restore(sess, "./fashion_mnist_cnn_model.ckpt")
             Z = logits.eval(feed_dict={X: X_test})
             y_test_cnn_pred = np.argmax(Z, axis=1)

         print("Test Accuracy",( y_test_cnn_pred == y_test).mean())# accuracy for test set
```

```
WARNING:tensorflow:From /anaconda3/lib/python3.6/site-packages/tensorflow/python/training/saver
Instructions for updating:
Use standard file APIs to check for files with this prefix.
INFO:tensorflow:Restoring parameters from ./fashion_mnist_cnn_model.ckpt
Test Accuracy 0.9133
```

```
In [33]: # Evaluating classifier
         confusion_matrix_plot(y_test, y_test_cnn_pred,
             filename="confusion_matrix_cnn_test",
             ymap={0:"T-shirt", 1:"Trouser", 2:"Pullover",3:"Dress",4:"Coat",5:"Sandal",
             6:"Shirt",7:"Sneaker",8:"Bag",9:"Ankle boot"},
             color=sns.diverging_palette(20,220, sep=10, n=25, s=90, l=45,center ='light'),
             midpoint=75,figsize=(15,12),v_min=0,v_max=1000)
```



0.6 Neural Nets

The training time is too long and results we obtain is not that good.

```
In [61]: def reset_graph(seed=42):
             tf.reset_default_graph()
             tf.set_random_seed(seed)
             np.random.seed(seed)
```

```
In [62]: from datetime import datetime

         now = datetime.utcnow().strftime("%Y%m%d%H%M%S")
         root_logdir = "."
         logdir = "{}//run-{}//".format(root_logdir, now)
```

```
In [63]: #define validation and training sets
         X_test = X_test.astype(np.int32)
         y_train = y_train.astype(np.int32)
```

```
y_test = y_test.astype(np.int32)
X_valid, X_train = X_train[:100], X_train[100:]
y_valid, y_train = y_train[:100], y_train[100:]


n_inputs = 784  # number of features
n_hidden1 = 147
n_hidden2 = 70
# dedfine more hidden layers
n_hidden3 = 50
n_outputs = 10
tf.reset_default_graph()   # reset graph


# y place holder for output
# auxialrry variable
X = tf.placeholder(tf.float32, shape=(None, n_inputs), name="X")
y = tf.placeholder(tf.int32, shape=(None), name="y")
a = tf.placeholder(tf.float32,shape=(None),name='a')


summary1 = tf.reduce_mean(a, name="summary1")

#layer of network takes input of neurones
def neuron_layer(X, n_neurons, name, activation=None):
    with tf.name_scope(name):
        n_inputs = int(X.get_shape()[1])
        stddev = 2 / np.sqrt(n_inputs)
        init = tf.truncated_normal((n_inputs, n_neurons), stddev=stddev)
        W = tf.Variable(init, name="kernel")
        b = tf.Variable(tf.zeros([n_neurons]), name="bias")
        Z = tf.matmul(X, W) + b
        if activation is not None:
            return activation(Z)
        else:
            return Z


with tf.name_scope("dnn"):
    hidden1 = neuron_layer(X, n_hidden1, name="hidden1", activation=tf.nn.relu)
    hidden2 = neuron_layer(hidden1, n_hidden2, name="hidden2", activation=tf.nn.relu)
    hidden3 = neuron_layer(hidden2, n_hidden3, name="hidden3", activation=tf.nn.relu)
    logits  = neuron_layer(hidden3, n_outputs, name="outputs")

with tf.name_scope("loss"):
    xentropy = tf.nn.sparse_softmax_cross_entropy_with_logits(labels=y, logits=logits
    loss = tf.reduce_mean(xentropy, name="loss")
```

```
         #learning rate - change if issues regrading convergence or others happen
         learning_rate =1e-1
         with tf.name_scope("train"):
             optimizer = tf.train.AdagradOptimizer(learning_rate)
             training_op = optimizer.minimize(loss)

         #define accuracy
         with tf.name_scope("accuracy"):
             correct = tf.nn.in_top_k(logits, y, 1)
             accuracy = tf.reduce_mean(tf.cast(correct, tf.float32))

         #leave this
         def shuffle_batch(X, y, batch_size):
             rnd_idx = np.random.permutation(len(X))
             n_batches = len(X) // batch_size
             for batch_idx in np.array_split(rnd_idx, n_batches):
                 X_batch, y_batch = X[batch_idx], y[batch_idx]
                 yield X_batch, y_batch
```

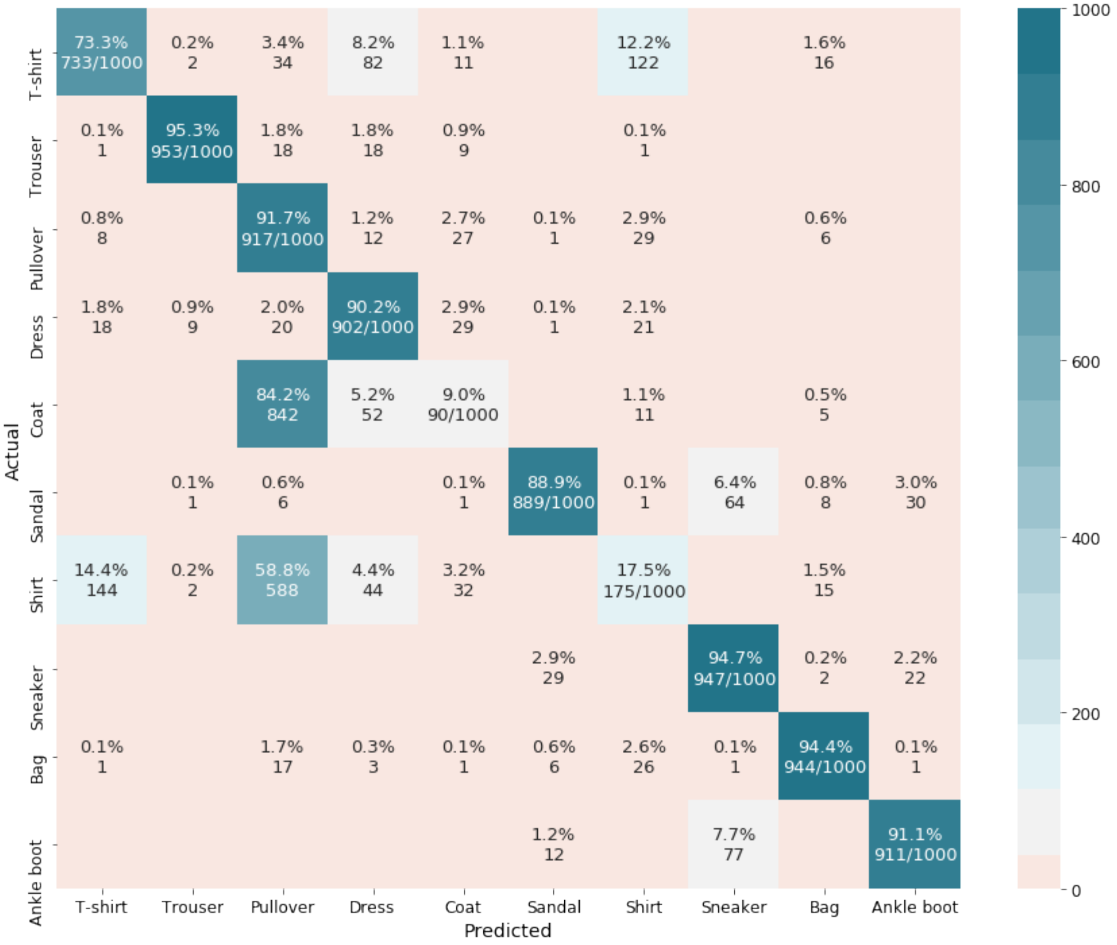
```
In [ ]: from random import randint
        n_epochs = 100
        batch_size = 100

        init = tf.global_variables_initializer()
        saver = tf.train.Saver()


        summary2 = tf.summary.scalar('Accuracy', summary1)
        file_writer = tf.summary.FileWriter(logdir , tf.get_default_graph())

        with tf.Session() as sess:
            init.run()
            acc_val = accuracy.eval(feed_dict={X: X_valid, y: y_valid})
            print("Val accuracy init:", acc_val)
            for epoch in range(n_epochs):
                for X_batch, y_batch in shuffle_batch(X_train, y_train, batch_size):
                    sess.run(training_op, feed_dict={X: X_batch, y: y_batch})
                acc_batch = accuracy.eval(feed_dict={X: X_batch, y: y_batch})
                acc_val = accuracy.eval(feed_dict={X: X_valid, y: y_valid})
                print(epoch, "Batch accuracy:", acc_batch, "Val accuracy:", acc_val)

                summary_str = summary2.eval(feed_dict={a: acc_val })
                file_writer.add_summary(summary_str, epoch)

            saver.save(sess, "./fashion_mnist_dnn_model.ckpt")
```

```
In [65]: with tf.Session() as sess:
             saver.restore(sess, "./fashion_mnist_dnn_model.ckpt")
```

```
        Z = logits.eval(feed_dict={X: X_test})
        y_test_dnn_pred = np.argmax(Z, axis=1)
```

```
INFO:tensorflow:Restoring parameters from ./fashion_mnist_dnn_model.ckpt
```

```
In [66]: # Evaluating classifier
         confusion_matrix_plot(y_test, y_test_dnn_pred,
             filename="confusion_matrix_dnn_test",
             ymap={0:"T-shirt", 1:"Trouser", 2:"Pullover",3:"Dress",4:"Coat",5:"Sandal",
             6:"Shirt",7:"Sneaker",8:"Bag",9:"Ankle boot"},
             color=sns.diverging_palette(20,220, sep=10, n=25, s=90, l=45,center ='light'),
             midpoint=75,figsize=(15,12),v_min=0,v_max=1000)
```



	T-shirt	Trouser	Pullover	Dress	Coat	Sandal	Shirt	Sneaker	Bag	Ankle boot
T-shirt	73.3% 733/1000	0.2% 2	3.4% 34	8.2% 82	1.1% 11		12.2% 122		1.6% 16	
Trouser	0.1% 1	95.3% 953/1000	1.8% 18	1.8% 18	0.9% 9		0.1% 1			
Pullover	0.8% 8		91.7% 917/1000	1.2% 12	2.7% 27	0.1% 1	2.9% 29		0.6% 6	
Dress	1.8% 18	0.9% 9	2.0% 20	90.2% 902/1000	2.9% 29	0.1% 1	2.1% 21			
Coat			84.2% 842	5.2% 52	9.0% 90/1000		1.1% 11		0.5% 5	
Sandal		0.1% 1	0.6% 6		0.1% 1	88.9% 889/1000	0.1% 1	6.4% 64	0.8% 8	3.0% 30
Shirt	14.4% 144	0.2% 2	58.8% 588	4.4% 44	3.2% 32		17.5% 175/1000		1.5% 15	
Sneaker						2.9% 29		94.7% 947/1000	0.2% 2	2.2% 22
Bag	0.1% 1		1.7% 17	0.3% 3	0.1% 1	0.6% 6	2.6% 26	0.1% 1	94.4% 944/1000	0.1% 1
Ankle boot						1.2% 12		7.7% 77		91.1% 911/1000

0.7 RNN

The training time is too long and results we obtain is not that good.

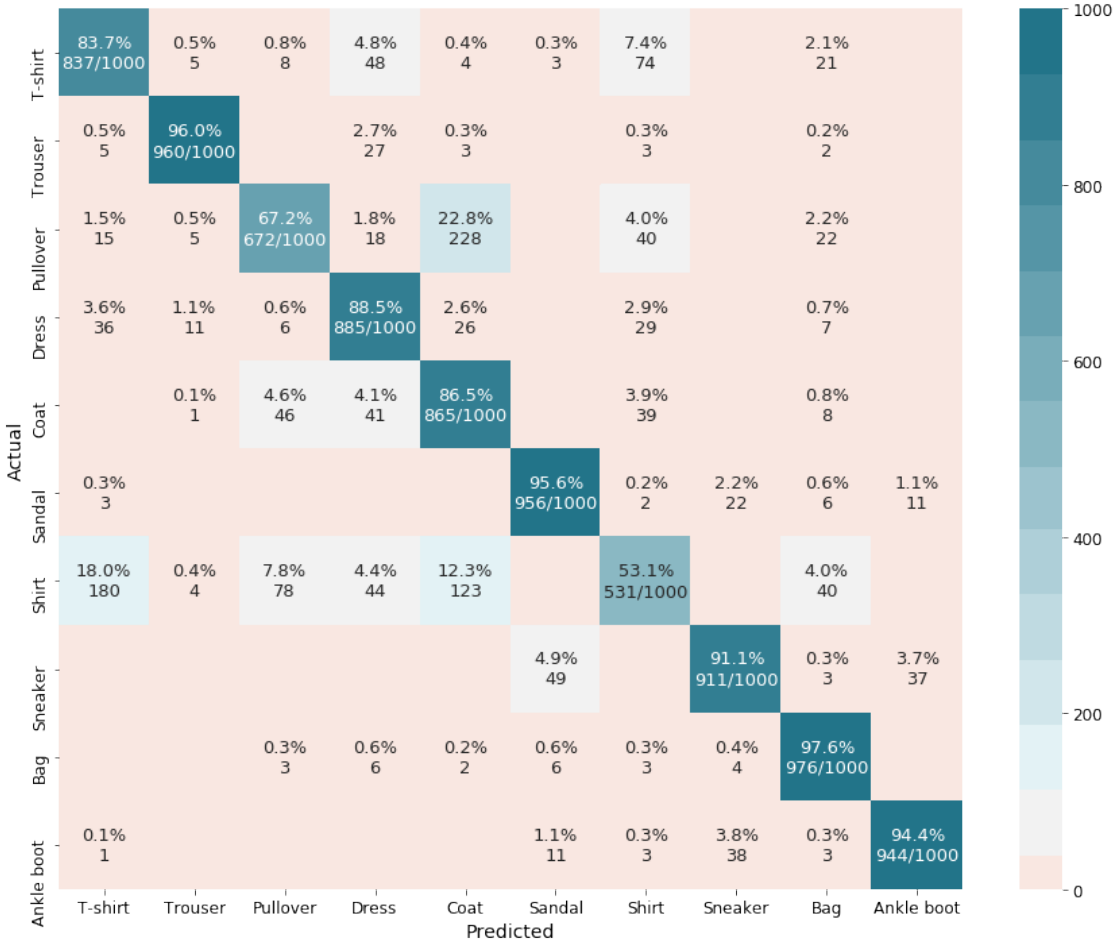
```
In [ ]: import tensorflow as tf

        reset_graph()

        n_steps = 28
        n_inputs = 28
        n_neurons = 150
        n_outputs = 10

        learning_rate = 0.001

        X = tf.placeholder(tf.float32, [None, n_steps, n_inputs])
        y = tf.placeholder(tf.int32, [None])

        basic_cell = tf.contrib.rnn.BasicRNNCell(num_units=n_neurons)
        outputs, states = tf.nn.dynamic_rnn(basic_cell, X, dtype=tf.float32)

        logits = tf.layers.dense(states, n_outputs)
        xentropy = tf.nn.sparse_softmax_cross_entropy_with_logits(labels=y,
                                                                   logits=logits)

        prediction = tf.argmax(logits, 1)

        loss = tf.reduce_mean(xentropy)
        optimizer = tf.train.AdamOptimizer(learning_rate=learning_rate)
        training_op = optimizer.minimize(loss)
        correct = tf.nn.in_top_k(logits, y, 1) # check if the prediction is corret [True, Fals
        accuracy = tf.reduce_mean(tf.cast(correct, tf.float32))

        init = tf.global_variables_initializer()

In [ ]: from tensorflow.examples.tutorials.mnist import input_data
        mnist = input_data.read_data_sets("FashionMnist-data")

        X_test = mnist.test.images.reshape((-1, n_steps, n_inputs))
        y_test = mnist.test.labels

In [69]: import time
         n_epochs = 10
         batch_size = 150
         start_time = time.time()
         saver = tf.train.Saver()

         with tf.Session() as sess:
             init.run()
             for epoch in range(n_epochs):
                 for iteration in range(mnist.train.num_examples // batch_size):
                     X_batch, y_batch = mnist.train.next_batch(batch_size)
                     X_batch = X_batch.reshape((-1, n_steps, n_inputs))
                     sess.run(training_op, feed_dict={X: X_batch, y: y_batch})
                     # print(iteration,end=' ')
                 acc_train = accuracy.eval(feed_dict={X: X_batch, y: y_batch})
                 acc_test = accuracy.eval(feed_dict={X: X_test, y: y_test})
                 print(epoch, "Test accuracy:", acc_test)
             saver.save(sess, "./fashion_mnist_rnn_model.ckpt")

         print("--- %s seconds ---" % (time.time() - start_time))
```

```
0 Test accuracy: 0.7962
1 Test accuracy: 0.8149
2 Test accuracy: 0.8262
3 Test accuracy: 0.8335
4 Test accuracy: 0.8429
5 Test accuracy: 0.8333
6 Test accuracy: 0.8426
7 Test accuracy: 0.8494
8 Test accuracy: 0.8477
9 Test accuracy: 0.8537
--- 83.00638699531555 seconds ---
```

```
In [70]: with tf.Session() as sess:
             saver.restore(sess, "./fashion_mnist_rnn_model.ckpt")
             prediction = tf.argmax(logits, axis=1)
             y_test_rnn_pred = sess.run(prediction, feed_dict={X: X_test})

         print("Test Accuracy",(y_test_rnn_pred == y_test).mean())# accuracy for test set
```

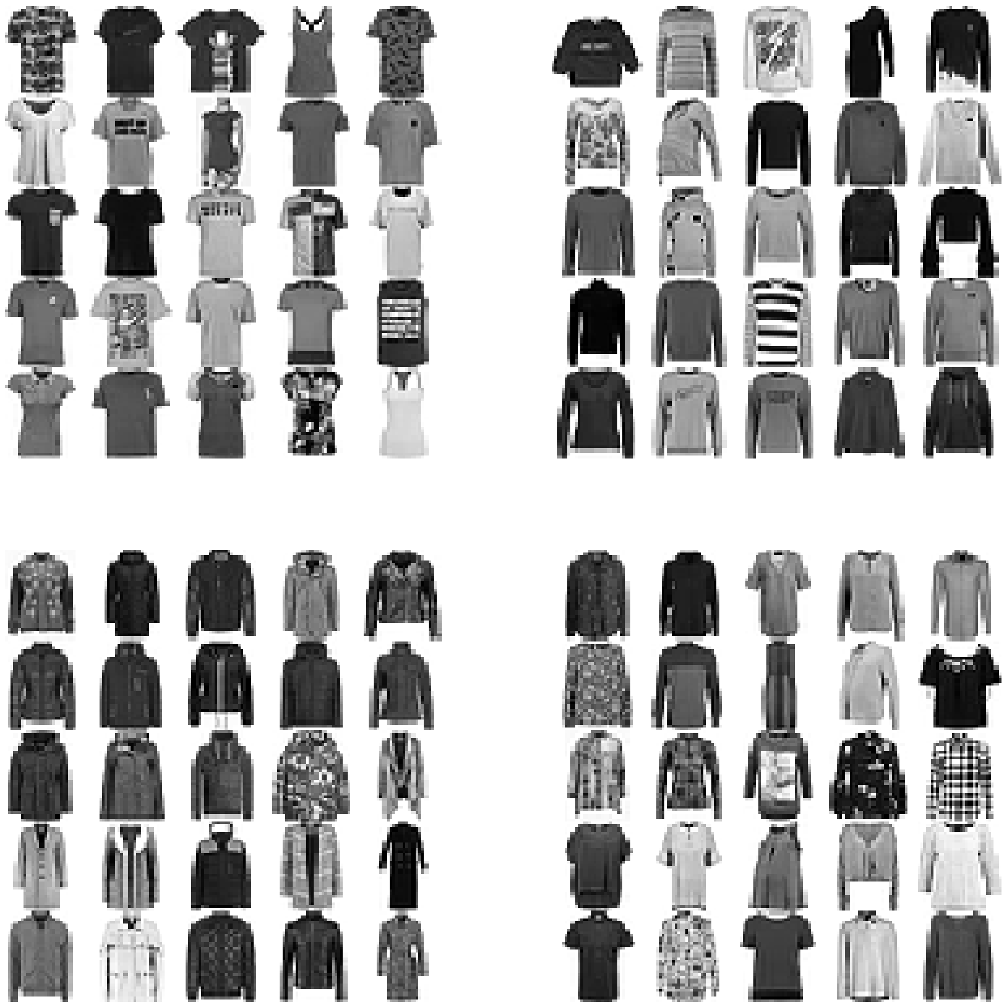
```
INFO:tensorflow:Restoring parameters from ./fashion_mnist_rnn_model.ckpt
Test Accuracy 0.8537
```

```
In [71]: # Evaluating classifier
         confusion_matrix_plot(y_test, y_test_rnn_pred,
             filename="confusion_matrix_rnn_test",
             ymap={0:"T-shirt", 1:"Trouser", 2:"Pullover",3:"Dress",4:"Coat",5:"Sandal",
             6:"Shirt",7:"Sneaker",8:"Bag",9:"Ankle boot"},
             color=sns.diverging_palette(20,220, sep=10, n=25, s=90, l=45,center ='light'),
             midpoint=75,figsize=(15,12),v_min=0,v_max=1000)
```



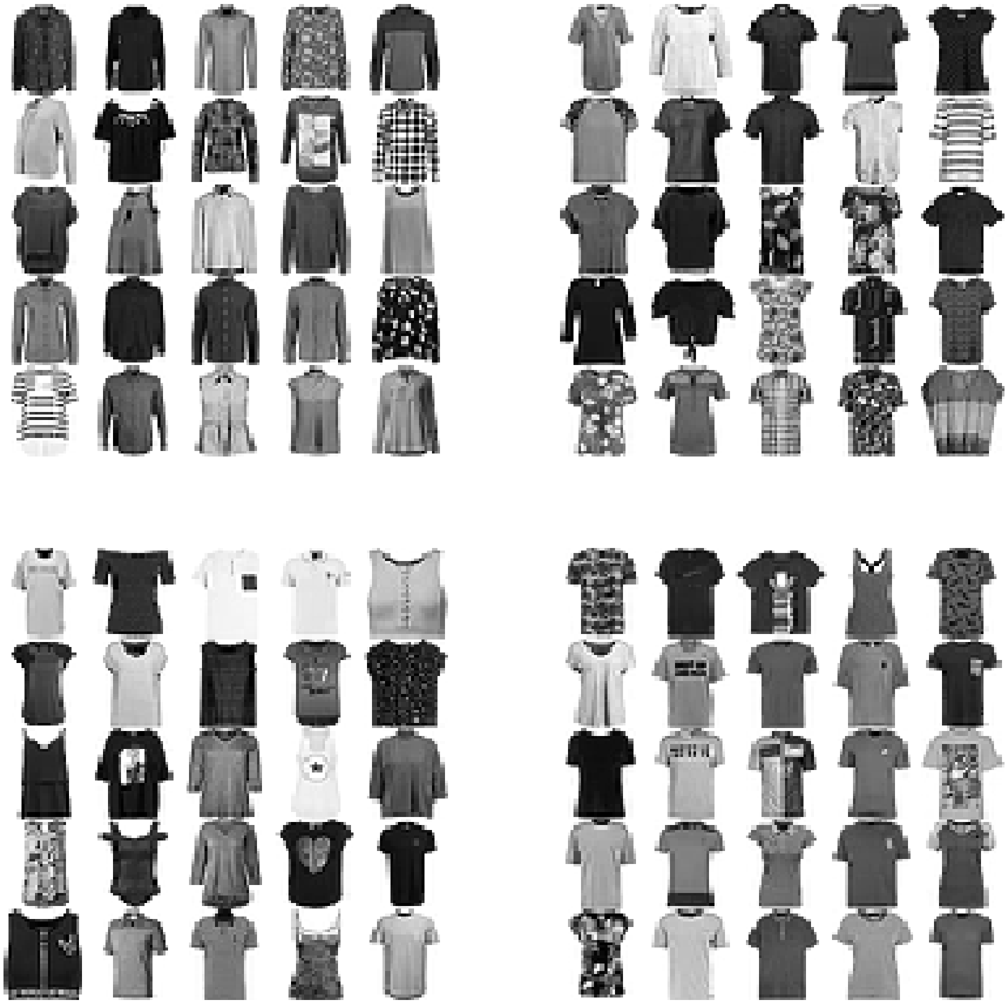
0.8 Error Analysis on training set for Logistic Regression Classifier

```
In [60]: # more errors happend to label 0,2,4,6
         X_0 = X_train[(y_train == 0)]
         X_2 = X_train[(y_train == 2)]
         X_4 = X_train[(y_train == 4)]
         X_6 = X_train[(y_train == 6)]

         plt.figure(figsize=(7,7))
         plt.subplot(221); plot_images(X_0[:25], images_per_row=5)
         plt.subplot(222); plot_images(X_2[:25], images_per_row=5)
         plt.subplot(223); plot_images(X_4[:25], images_per_row=5)
         plt.subplot(224); plot_images(X_6[:25], images_per_row=5)
         # save_fig("images_for_labels_0&2&4&6")
```



```
In [59]: # error analysis : label 2 and 4
         cl_a, cl_b = 2, 4
         X_aa = X_train[(y_train == cl_a) & (y_train_logit_pred == cl_a)]
         X_ab = X_train[(y_train == cl_a) & (y_train_logit_pred == cl_b)]
         X_ba = X_train[(y_train == cl_b) & (y_train_logit_pred == cl_a)]
         X_bb = X_train[(y_train == cl_b) & (y_train_logit_pred == cl_b)]
         plt.figure(figsize=(5,7))
         plt.subplot(221); plot_images(X_aa[:9], images_per_row=3)
         plt.subplot(222); plot_images(X_ab[:9], images_per_row=3)
         plt.subplot(223); plot_images(X_ba[:9], images_per_row=3)
         plt.subplot(224); plot_images(X_bb[:9], images_per_row=3)
         # save_fig("error_analysis_images_plot_2&4")
         plt.show()
```

```
In [58]: # error analysis : label 6 and 0
         cl_a, cl_b = 6, 0
         X_aa = X_train[(y_train == cl_a) & (y_train_logit_pred == cl_a)]
         X_ab = X_train[(y_train == cl_a) & (y_train_logit_pred == cl_b)]
         X_ba = X_train[(y_train == cl_b) & (y_train_logit_pred == cl_a)]
         X_bb = X_train[(y_train == cl_b) & (y_train_logit_pred == cl_b)]

         plt.figure(figsize=(7,7))
         plt.subplot(221); plot_images(X_aa[:25], images_per_row=5)
         plt.subplot(222); plot_images(X_ab[:25], images_per_row=5)
         plt.subplot(223); plot_images(X_ba[:25], images_per_row=5)
         plt.subplot(224); plot_images(X_bb[:25], images_per_row=5)
         # save_fig("error_analysis_images_plot_6&0")
         plt.show()
```



```
In [57]: # error analysis : label 6 and 0
         cl_a, cl_b = 2, 8
         X_aa = X_train[(y_train == cl_a) & (y_train_logit_pred == cl_a)]
         X_ab = X_train[(y_train == cl_a) & (y_train_logit_pred == cl_b)]
         X_ba = X_train[(y_train == cl_b) & (y_train_logit_pred == cl_a)]
         X_bb = X_train[(y_train == cl_b) & (y_train_logit_pred == cl_b)]

         plt.figure(figsize=(7,7))
         plt.subplot(221); plot_images(X_aa[:16], images_per_row=4)
         plt.subplot(222); plot_images(X_ab[:16], images_per_row=4)
         plt.subplot(223); plot_images(X_ba[:16], images_per_row=4)
         plt.subplot(224); plot_images(X_bb[:16], images_per_row=4)
         # save_fig("error_analysis_images_plot_2&8")
         plt.show()
```

0.9 Error Analysis on training set for Logistic Regression Classifier

```
In [56]: # more errors happend to label 0,2,4,6
         X_0 = X_test[(y_test == 0)]
         X_2 = X_test[(y_test == 2)]
         X_4 = X_test[(y_test == 4)]
         X_6 = X_test[(y_test == 6)]

         plt.figure(figsize=(7,7))
         plt.subplot(221); plot_images(X_0[:25], images_per_row=5)
         plt.subplot(222); plot_images(X_2[:25], images_per_row=5)
         plt.subplot(223); plot_images(X_4[:25], images_per_row=5)
         plt.subplot(224); plot_images(X_6[:25], images_per_row=5)
```

```
        save_fig("images_for_labels_0&2&4&6")
        plt.show()
```

```
Saving figure images_for_labels_0&2&4&6
```

```
In [48]: # more errors happend to label 5,7,9
         X_5 = X_test[(y_test == 5)]
         X_7 = X_test[(y_test == 7)]
         X_9 = X_test[(y_test == 9)]

         plt.figure(figsize=(9,9))
         plt.subplot(131); plot_images(X_5[:25], images_per_row=5)
         plt.subplot(132); plot_images(X_7[:25], images_per_row=5)
```

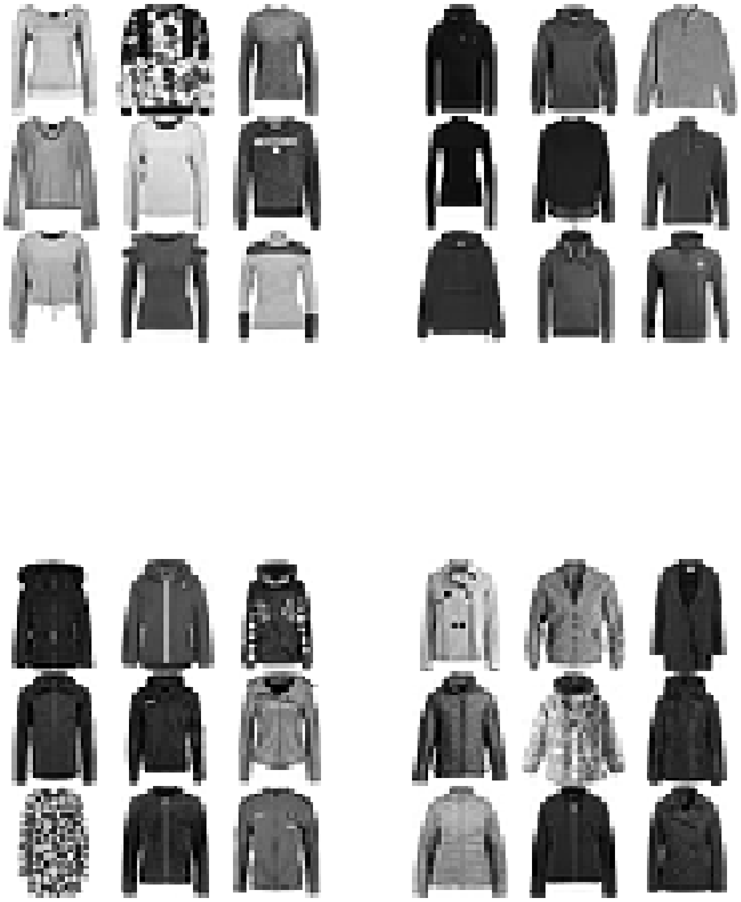
```
        plt.subplot(133); plot_images(X_9[:25], images_per_row=5)
        save_fig("images_for_labels_5&7&9")
        plt.show()
```

```
Saving figure images_for_labels_5&7&9
```

```
In [49]: # error analysis : label 5 and 7
         cl_a, cl_b = 5, 7
         X_aa = X_test[(y_test == cl_a) & (y_test_logit_pred == cl_a)]
         X_ab = X_test[(y_test == cl_a) & (y_test_logit_pred == cl_b)]
         X_ba = X_test[(y_test == cl_b) & (y_test_logit_pred == cl_a)]
         X_bb = X_test[(y_test == cl_b) & (y_test_logit_pred == cl_b)]

         plt.figure(figsize=(5,7))
         plt.subplot(221); plot_images(X_aa[:9], images_per_row=3)
         plt.subplot(222); plot_images(X_ab[:9], images_per_row=3)
         plt.subplot(223); plot_images(X_ba[:9], images_per_row=3)
         plt.subplot(224); plot_images(X_bb[:9], images_per_row=3)
         # save_fig("error_analysis_images_plot_5&7")
         plt.show()
```

```
In [53]: # error analysis : label 7 and 9
         cl_a, cl_b = 7, 9
         X_aa = X_test[(y_test == cl_a) & (y_test_logit_pred == cl_a)]
         X_ab = X_test[(y_test == cl_a) & (y_test_logit_pred == cl_b)]
         X_ba = X_test[(y_test == cl_b) & (y_test_logit_pred == cl_a)]
         X_bb = X_test[(y_test == cl_b) & (y_test_logit_pred == cl_b)]

         plt.figure(figsize=(5,7))
         plt.subplot(221); plot_images(X_aa[:16], images_per_row=4)
         plt.subplot(222); plot_images(X_ab[:16], images_per_row=4)
         plt.subplot(223); plot_images(X_ba[:16], images_per_row=4)
         plt.subplot(224); plot_images(X_bb[:16], images_per_row=4)
         # save_fig("error_analysis_images_plot_7&9")
         plt.show()
```

```
In [55]: # error analysis : label 2 and 4
         cl_a, cl_b = 2, 4
         X_aa = X_test[(y_test == cl_a) & (y_test_logit_pred == cl_a)]
         X_ab = X_test[(y_test == cl_a) & (y_test_logit_pred == cl_b)]
         X_ba = X_test[(y_test == cl_b) & (y_test_logit_pred == cl_a)]
         X_bb = X_test[(y_test == cl_b) & (y_test_logit_pred == cl_b)]

         plt.figure(figsize=(5,7))
         plt.subplot(221); plot_images(X_aa[:9], images_per_row=3)
         plt.subplot(222); plot_images(X_ab[:9], images_per_row=3)
         plt.subplot(223); plot_images(X_ba[:9], images_per_row=3)
         plt.subplot(224); plot_images(X_bb[:9], images_per_row=3)
         # save_fig("error_analysis_images_plot_2&4")
         plt.show()
```



In [54]:
```
# error analysis : label 6 and 0
cl_a, cl_b = 6, 0
X_aa = X_test[(y_test == cl_a) & (y_test_logit_pred == cl_a)]
X_ab = X_test[(y_test == cl_a) & (y_test_logit_pred == cl_b)]
X_ba = X_test[(y_test == cl_b) & (y_test_logit_pred == cl_a)]
X_bb = X_test[(y_test == cl_b) & (y_test_logit_pred == cl_b)]

plt.figure(figsize=(5,7))
plt.subplot(221); plot_images(X_aa[:9], images_per_row=3)
plt.subplot(222); plot_images(X_ab[:9], images_per_row=3)
plt.subplot(223); plot_images(X_ba[:9], images_per_row=3)
plt.subplot(224); plot_images(X_bb[:9], images_per_row=3)
# save_fig("error_analysis_images_plot_6&0")
plt.show()
```