Clothing Classification

Description

Fashion training set consists of 70,000 images divided into 60,000 training and 10,000 testing samples. Dataset sample consists of 28x28 grayscale image, associated with a label from 10 classes.

The 10 classes are as follows:
0 = T-shirt/top
1 = Trouser
2 = Pullover
3 = Dress
4 = Coat
5 = Sandal
6 = Shirt
7 = Sneaker
8 = Bag
9 = Ankle boot

Each image is 28 pixels in height and 28 pixels in width, for a total of 784 pixels in total. Each pixel has a single pixel-value associated with it, indicating the lightness or darkness of that pixel, with higher numbers meaning darker. This pixel-value is an integer between 0 and 255.

Importing the dataset

In [1]:

```
# Importing required libraries

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
```

In [3]:

```
# Let's create training and testing dataframes using CSV files

training_df = pd.read_csv('train_data.csv')
testing_df = pd.read_csv('test_data.csv')
```

Visualizing the data

In [4]:

```
# Let's check first 5 rows of training dataframe

training_df.head()
```

Out[4]:

	label	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	...	pixel775	pixel776	pi
0	2	0	0	0	0	0	0	0	0	0	...	0	0	
1	9	0	0	0	0	0	0	0	0	0	...	0	0	
2	6	0	0	0	0	0	0	0	5	0	...	0	0	
3	0	0	0	0	1	2	0	0	0	0	...	3	0	
4	3	0	0	0	0	0	0	0	0	0	...	0	0	

5 rows × 785 columns

In [5]:
```python
# Let's check last 5 rows of training dataframe

training_df.tail()
```

Out[5]:

	label	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	...	pixel775	pixel77
59995	9	0	0	0	0	0	0	0	0	0	...	0	
59996	1	0	0	0	0	0	0	0	0	0	...	73	
59997	8	0	0	0	0	0	0	0	0	0	...	160	16
59998	8	0	0	0	0	0	0	0	0	0	...	0	
59999	7	0	0	0	0	0	0	0	0	0	...	0	

5 rows × 785 columns

Observations

1. There are 784 columns with various pixel values of different images
2. First column (i.e. label) is the column to be predicted. We will ignore the same initially.
3. There are 60000 observations in training dataset
4. All pixel values are between 0 to 255

In [6]:
```python
# Let's check first 5 rows of testing dataframe

testing_df.head()
```

Out[6]:

	label	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	...	pixel775	pixel776	pi
0	0	0	0	0	0	0	0	0	9	8	...	103	87	
1	1	0	0	0	0	0	0	0	0	0	...	34	0	
2	2	0	0	0	0	0	0	14	53	99	...	0	0	
3	2	0	0	0	0	0	0	0	0	0	...	137	126	
4	3	0	0	0	0	0	0	0	0	0	...	0	0	

5 rows × 785 columns

In [7]:
```python
# Let's check last 5 rows of testing dataframe

testing_df.tail()
```

Out[7]:

	label	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	...	pixel775	pixel776
9995	0	0	0	0	0	0	0	0	0	0	...	32	23
9996	6	0	0	0	0	0	0	0	0	0	...	0	0
9997	8	0	0	0	0	0	0	0	0	0	...	175	172
9998	8	0	1	3	0	0	0	0	0	0	...	0	0
9999	1	0	0	0	0	0	0	0	140	119	...	111	95

5 rows × 785 columns

Observations

1. There are 784 columns with various pixel values of different images
2. There are 10000 observations in testing dataset
3. All pixel values are between 0 to 255

In [8]:
```python
# Let's create numpy arrays for training and testing dataframes
# using float values for further processing

trainData = np.array(training_df, dtype='float32')
testData = np.array(testing_df, dtype='float32')
```

In [9]:
```python
# Let's check the training data and it's shape

print(trainData)
print('\n')
print(trainData.shape)
```

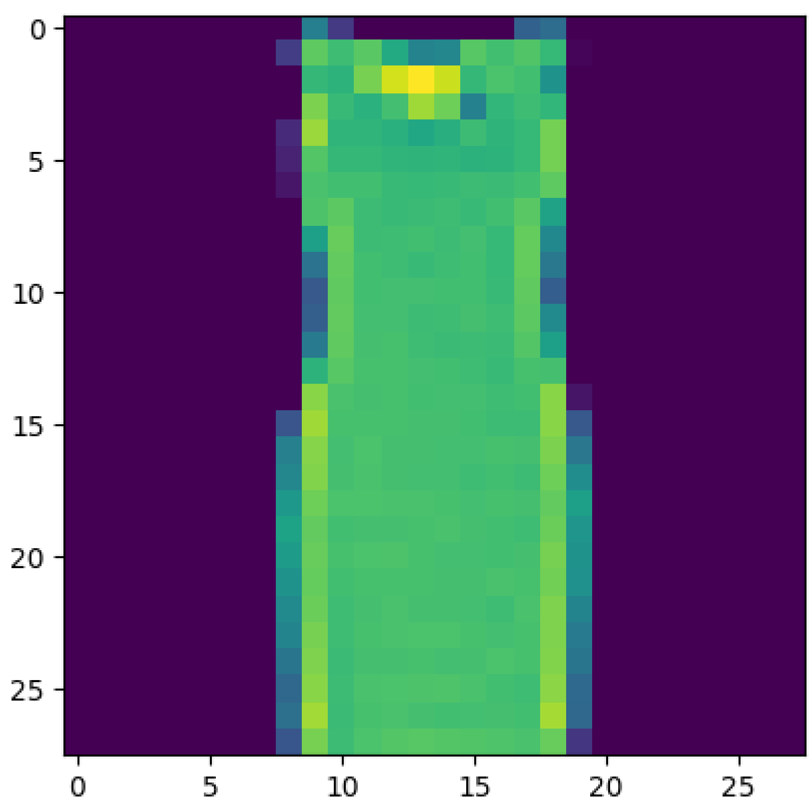
```
[[2. 0. 0. ... 0. 0. 0.]
 [9. 0. 0. ... 0. 0. 0.]
 [6. 0. 0. ... 0. 0. 0.]
 ...
 [8. 0. 0. ... 0. 0. 0.]
 [8. 0. 0. ... 0. 0. 0.]
 [7. 0. 0. ... 0. 0. 0.]]


(60000, 785)
```

In [10]:
```python
# Let's check the testing data

print(testData)
print('\n')
print(testData.shape)
```

```
[[0. 0. 0. ... 0. 0. 0.]
 [1. 0. 0. ... 0. 0. 0.]
 [2. 0. 0. ... 0. 0. 0.]
 ...
 [8. 0. 0. ... 0. 1. 0.]
 [8. 0. 1. ... 0. 0. 0.]
 [1. 0. 0. ... 0. 0. 0.]]


(10000, 785)
```

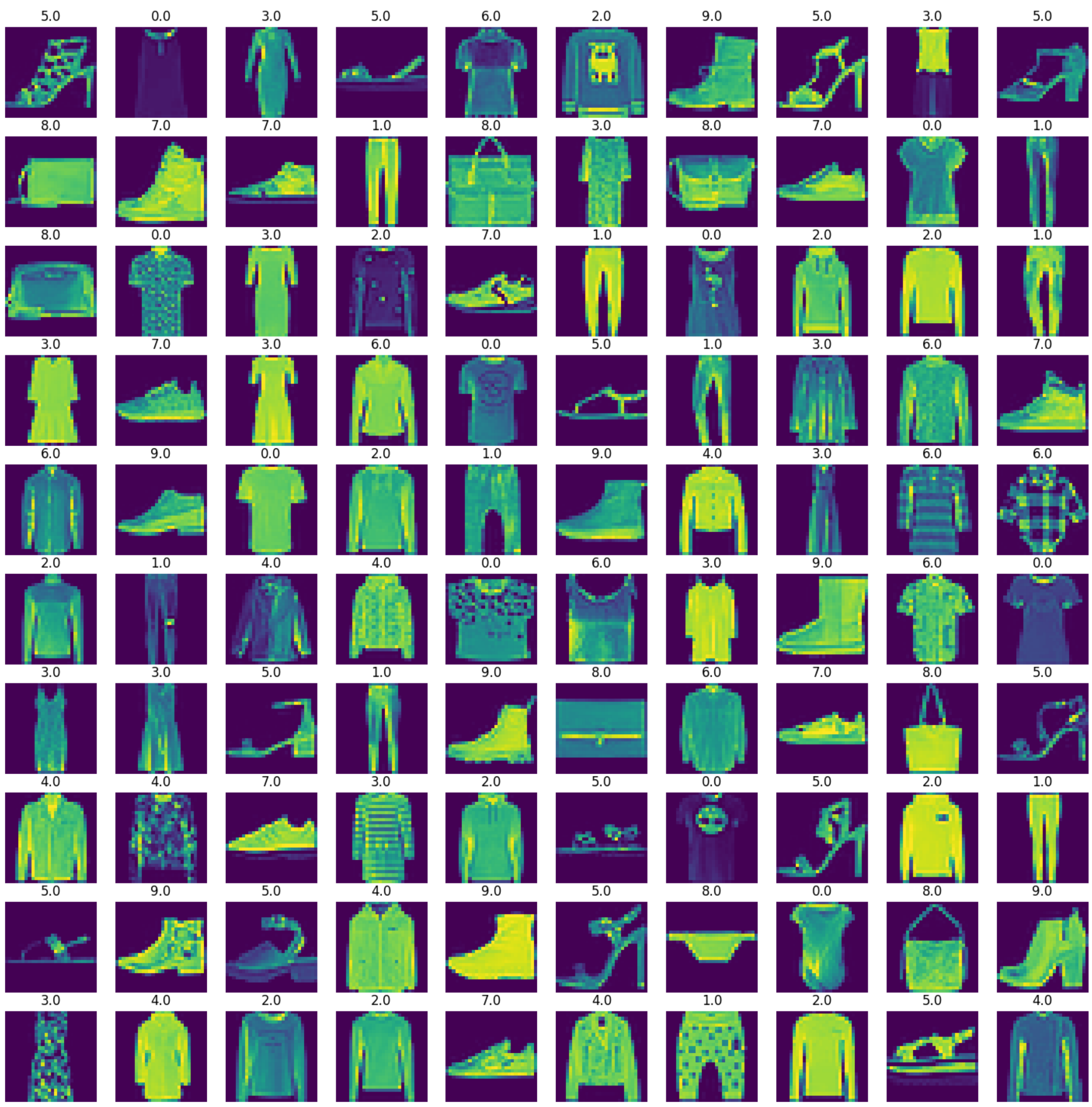
In [11]:
```
# Let's visualize an image randomly using any random number from training d

# Importing library random to get any random number

import random
i = random.randint(1, trainData.shape[0])

# Displaying a random image using pixel values(reshaped)

plt.imshow(trainData[i, 1:].reshape(28, 28))
print(trainData[i, 0])

# Let's check all class values with labels for reference

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

```
3.0
```



In [12]:

```python
# Let's view multiple images in a grid format

Grid_W = 10 # Number of columns
Grid_H = 10 # Number of rows

# Let's create subplot to display multiple images

fig, axes = plt.subplots(nrows=Grid_H, ncols=Grid_W, figsize = (18,18))
axes = axes.ravel()

# Let's loop through the training dataset to display random 100 images

for i in np.arange(0, Grid_W*Grid_H):
    index = np.random.randint(0, len(trainData))
    axes[i].imshow(trainData[index, 1:].reshape(28, 28))
    axes[i].set_title(trainData[index, 0])
    axes[i].axis('off')
```



Splitting and reshaping the data

In [13]:

```python
# Let's split the data into initial X_train and y_train data
# Normalizing each pixel value by dividing the same with 255
# i.e. Converting all pixel values between range 0 to 1

X_train_init = trainData[:, 1:] / 255
y_train_init = trainData[:, 0]

# Let's do the same for test data

X_test = testData[:, 1:] / 255
y_test = testData[:, 0]
```

In [14]:
```
# Let's split the training data further to create training and validation d

# Importing necessary library

from sklearn.model_selection import train_test_split
X_train, X_valid, y_train, y_valid = train_test_split(X_train_init, y_train
                                                      test_size=0.2, random
```

In [15]:
```
X_train.shape
```

Out[15]:
```
(48000, 784)
```

In [16]:
```
X_valid.shape
```

Out[16]:
```
(12000, 784)
```

In [17]:
```
# Let's reshape the array similar to an image data e.g. (row, column, chann

X_train = X_train.reshape(X_train.shape[0], 28, 28, 1)
X_test = X_test.reshape(X_test.shape[0], 28, 28, 1)
X_valid = X_valid.reshape(X_valid.shape[0], 28, 28, 1)
```

In [18]:
```
# Let's check the new shape of the training, testing and validation data

X_train.shape
```

Out[18]:
```
(48000, 28, 28, 1)
```

In [19]:
```
X_test.shape
```

Out[19]:
```
(10000, 28, 28, 1)
```

In [20]:
```
X_valid.shape
```

Out[20]:
```
(12000, 28, 28, 1)
```

Training a Neural Network Model

In [21]:
```
import tensorflow as tf
```

First model

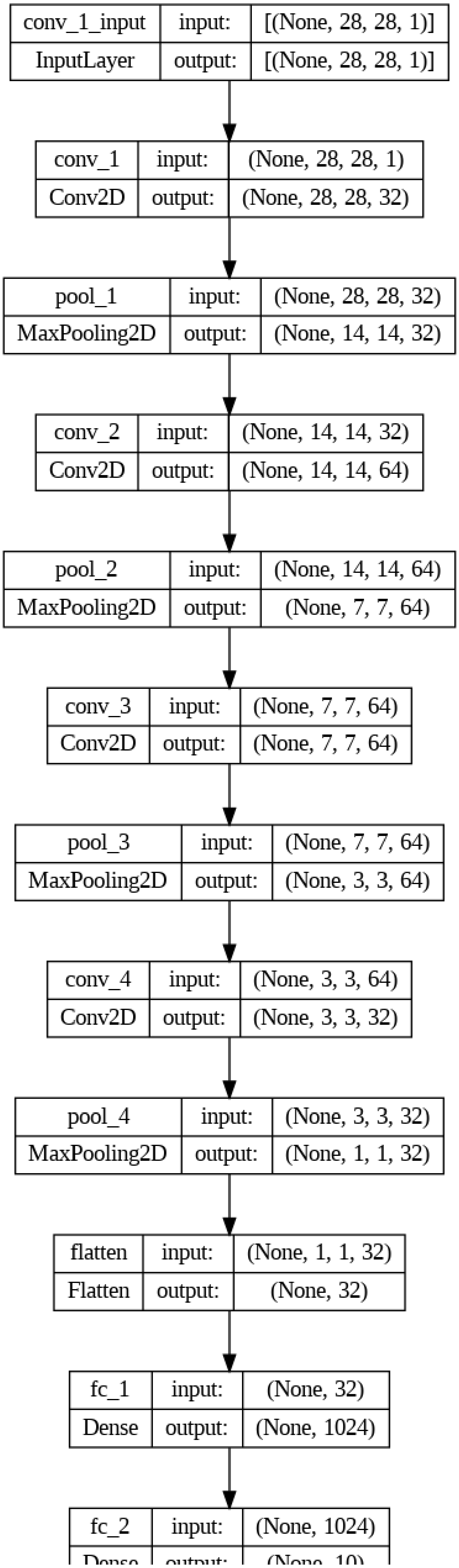
In [22]:
```
##########################
# design your first model
##########################

model = tf.keras.Sequential()
model.add(tf.keras.layers.Conv2D(filters=32, kernel_size=(5, 5),strides=(1,
model.add(tf.keras.layers.MaxPool2D(pool_size=(2, 2), name='pool_1'))
model.add(tf.keras.layers.Conv2D(filters=64, kernel_size=(5, 5),strides=(1,
model.add(tf.keras.layers.MaxPool2D(pool_size=(2, 2), name='pool_2'))
model.add(tf.keras.layers.Conv2D(filters=64, kernel_size=(5, 5),strides=(1,
model.add(tf.keras.layers.MaxPool2D(pool_size=(2, 2), name='pool_3'))
model.add(tf.keras.layers.Conv2D(filters=32, kernel_size=(5, 5),strides=(1,
model.add(tf.keras.layers.MaxPool2D(pool_size=(2, 2), name='pool_4'))
model.add(tf.keras.layers.Flatten())
model.add(tf.keras.layers.Dense(units=1024, name='fc_1', activation='relu')
model.add(tf.keras.layers.Dense(units=10, name='fc_2',activation='softmax')
model.build(input_shape=(None, 28, 28, 1))
```

In [23]:
```
model.compute_output_shape(input_shape=(10000, 28, 28, 1))
```

Out[23]:
```
TensorShape([10000, 10])
```

In [24]:
```
tf.keras.utils.plot_model(model, show_shapes=True, show_layer_names=True)
```

Out[24]:


conv_1_input
input:
[(None, 28, 28, 1)]
InputLayer
output:
[(None, 28, 28, 1)]
conv_1
input:
(None, 28, 28, 1)
Conv2D
output:
(None, 28, 28, 32)
pool_1
input:
(None, 28, 28, 32)
MaxPooling2D
output:
(None, 14, 14, 32)
conv_2
input:
(None, 14, 14, 32)
Conv2D
output:
(None, 14, 14, 64)
pool_2
input:
(None, 14, 14, 64)
MaxPooling2D
output:
(None, 7, 7, 64)
conv_3
input:
(None, 7, 7, 64)
Conv2D
output:
(None, 7, 7, 64)
pool_3
input:
(None, 7, 7, 64)
MaxPooling2D
output:
(None, 3, 3, 64)
conv_4
input:
(None, 3, 3, 64)
Conv2D
output:
(None, 3, 3, 32)
pool_4
input:
(None, 3, 3, 32)
MaxPooling2D
output:
(None, 1, 1, 32)
flatten
input:
(None, 1, 1, 32)
Flatten
output:
(None, 32)
fc_1
input:
(None, 32)
Dense
output:
(None, 1024)
fc_2
input:
(None, 1024)

Dense	output:	(None, 10)

In [25]:
```
##############################
# compile your first model
#############################
model.compile(optimizer=tf.keras.optimizers.Adam(),loss=tf.keras.losses.Spa
```

In [26]:
```
###########################
# get summary of your model
###########################
model.summary()
```

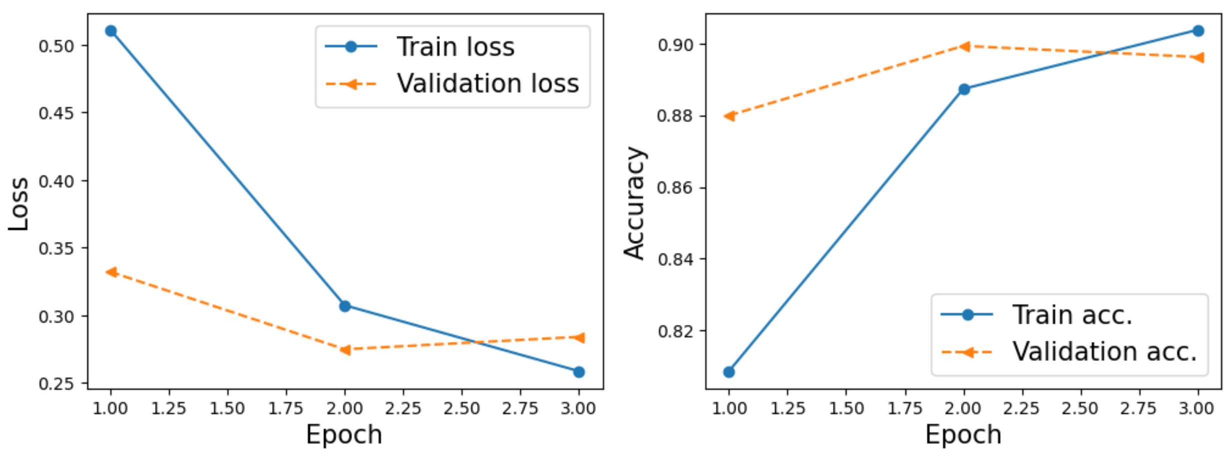
```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv_1 (Conv2D)             (None, 28, 28, 32)        832

 pool_1 (MaxPooling2D)       (None, 14, 14, 32)        0

 conv_2 (Conv2D)             (None, 14, 14, 64)        51264

 pool_2 (MaxPooling2D)       (None, 7, 7, 64)          0

 conv_3 (Conv2D)             (None, 7, 7, 64)          102464

 pool_3 (MaxPooling2D)       (None, 3, 3, 64)          0

 conv_4 (Conv2D)             (None, 3, 3, 32)          51232

 pool_4 (MaxPooling2D)       (None, 1, 1, 32)          0

 flatten (Flatten)           (None, 32)                0

 fc_1 (Dense)                (None, 1024)              33792

 fc_2 (Dense)                (None, 10)                10250

=================================================================
Total params: 249834 (975.91 KB)
Trainable params: 249834 (975.91 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

In [27]:
```
#######################
# fit your first model
#######################
history = model.fit(X_train, y_train, epochs=3, validation_data=(X_valid, y
```

```
Epoch 1/3

/usr/local/lib/python3.10/dist-packages/keras/src/backend.py:5727: UserWa
rning: "`sparse_categorical_crossentropy` received `from_logits=True`, bu
t the `output` argument was produced by a Softmax activation and thus doe
s not represent logits. Was this intended?
  output, from_logits = _get_logits(

1500/1500 [==============================] - 173s 114ms/step - loss: 0.51
09 - accuracy: 0.8086 - val_loss: 0.3320 - val_accuracy: 0.8799
Epoch 2/3
1500/1500 [==============================] - 170s 113ms/step - loss: 0.30
73 - accuracy: 0.8873 - val_loss: 0.2748 - val_accuracy: 0.8993
Epoch 3/3
1500/1500 [==============================] - 168s 112ms/step - loss: 0.25
86 - accuracy: 0.9038 - val_loss: 0.2840 - val_accuracy: 0.8963
```

In [28]:

```
###########################################################################
# evaluate your first model and and plot your training curve and show class
###########################################################################
hist = history.history
x_arr = np.arange(len(hist['loss'])) + 1

fig = plt.figure(figsize=(12, 4))
ax = fig.add_subplot(1, 2, 1)
ax.plot(x_arr, hist['loss'], '-o', label='Train loss')
ax.plot(x_arr, hist['val_loss'], '--<', label='Validation loss')
ax.set_xlabel('Epoch', size=15)
ax.set_ylabel('Loss', size=15)
ax.legend(fontsize=15)
ax = fig.add_subplot(1, 2, 2)
ax.plot(x_arr, hist['accuracy'], '-o', label='Train acc.')
ax.plot(x_arr, hist['val_accuracy'], '--<', label='Validation acc.')
ax.legend(fontsize=15)
ax.set_xlabel('Epoch', size=15)
ax.set_ylabel('Accuracy', size=15)

plt.show()
```



In [29]:

```
test_results = model.evaluate(X_test , y_test)
print(f"Test Accuracy is {test_results[1]*100}")
```

```
313/313 [==============================] - 10s 30ms/step - loss: 0.2686 -
accuracy: 0.8985
Test Accuracy is 89.85000252723694
```

Second model

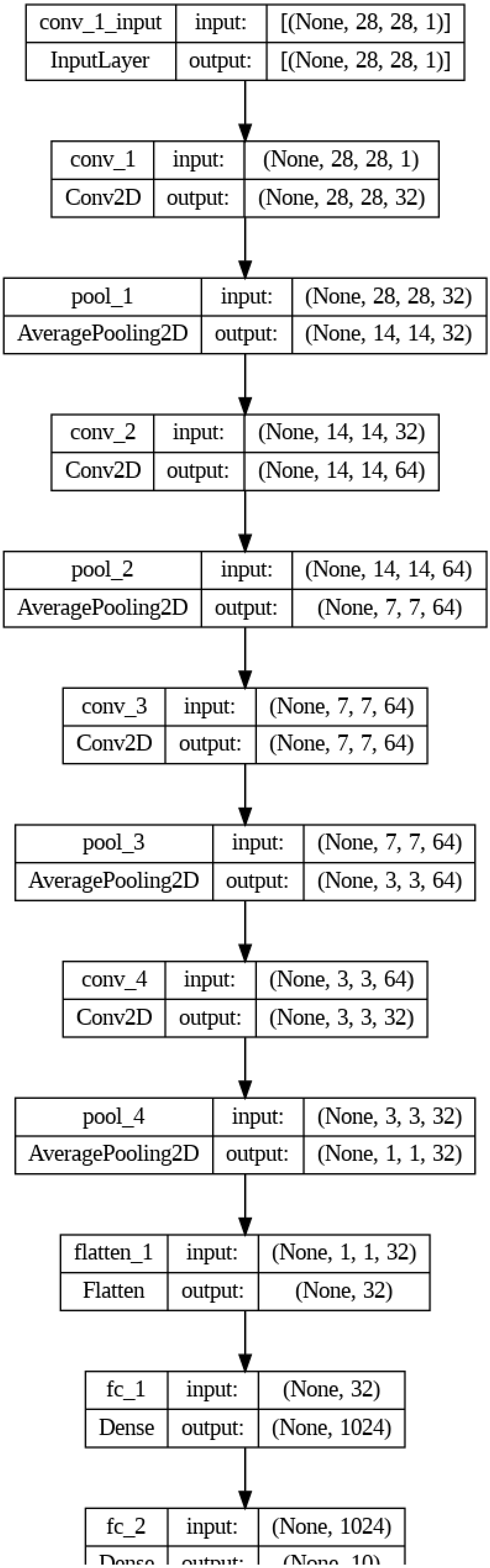
In [30]:

```
##########################
# design your second model
##########################

model = tf.keras.Sequential()
model.add(tf.keras.layers.Conv2D(filters=32, kernel_size=(5, 5),strides=(1,
model.add(tf.keras.layers.AveragePooling2D(pool_size=(2, 2), name='pool_1')
model.add(tf.keras.layers.Conv2D(filters=64, kernel_size=(5, 5),strides=(1,
model.add(tf.keras.layers.AveragePooling2D(pool_size=(2, 2), name='pool_2')
model.add(tf.keras.layers.Conv2D(filters=64, kernel_size=(5, 5),strides=(1,
model.add(tf.keras.layers.AveragePooling2D(pool_size=(2, 2), name='pool_3')
model.add(tf.keras.layers.Conv2D(filters=32, kernel_size=(5, 5),strides=(1,
model.add(tf.keras.layers.AveragePooling2D(pool_size=(2, 2), name='pool_4')
model.add(tf.keras.layers.Flatten())
model.add(tf.keras.layers.Dense(units=1024, name='fc_1', activation='relu')
model.add(tf.keras.layers.Dense(units=10, name='fc_2',activation='softmax')
model.build(input_shape=(None, 28, 28, 1))
```

In [31]:

```
tf.keras.utils.plot_model(model, show_shapes=True, show_layer_names=True)
```

Out[31]:



conv_1_input
InputLayer
input:
output:
[(None, 28, 28, 1)]
[(None, 28, 28, 1)]
conv_1
Conv2D
input:
output:
(None, 28, 28, 1)
(None, 28, 28, 32)
pool_1
AveragePooling2D
input:
output:
(None, 28, 28, 32)
(None, 14, 14, 32)
conv_2
Conv2D
input:
output:
(None, 14, 14, 32)
(None, 14, 14, 64)
pool_2
AveragePooling2D
input:
output:
(None, 14, 14, 64)
(None, 7, 7, 64)
conv_3
Conv2D
input:
output:
(None, 7, 7, 64)
(None, 7, 7, 64)
pool_3
AveragePooling2D
input:
output:
(None, 7, 7, 64)
(None, 3, 3, 64)
conv_4
Conv2D
input:
output:
(None, 3, 3, 64)
(None, 3, 3, 32)
pool_4
AveragePooling2D
input:
output:
(None, 3, 3, 32)
(None, 1, 1, 32)
flatten_1
Flatten
input:
output:
(None, 1, 1, 32)
(None, 32)
fc_1
Dense
input:
output:
(None, 32)
(None, 1024)
fc_2
input:
(None, 1024)

Dense | output: | (None, 10)

In [32]:
```
##########################
compile your first model
##########################
del.compile(optimizer=tf.keras.optimizers.Adam(),loss=tf.keras.losses.Sparse
```

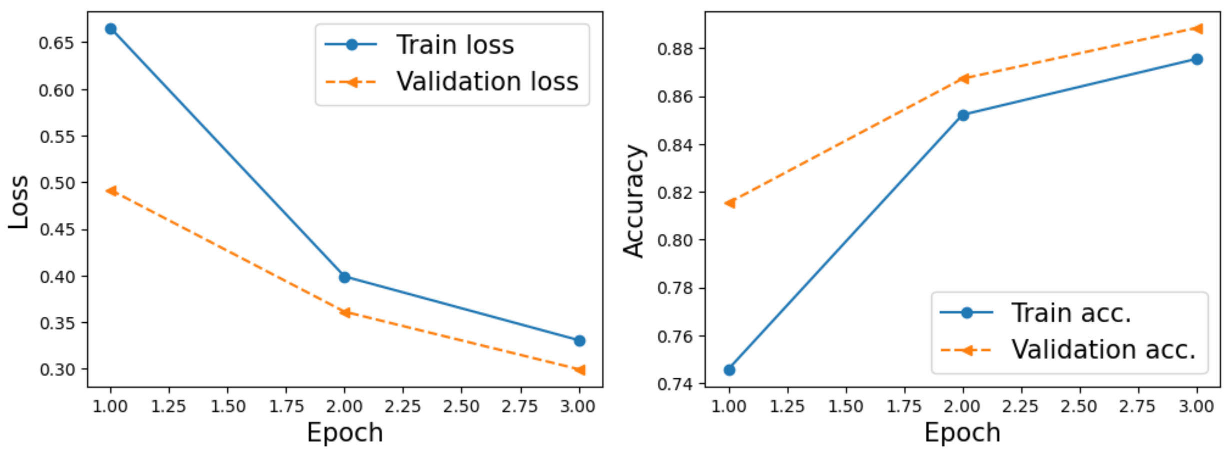
In [33]:
```
##########################
# get summary of your model
##########################
model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv_1 (Conv2D)             (None, 28, 28, 32)        832

 pool_1 (AveragePooling2D)   (None, 14, 14, 32)        0

 conv_2 (Conv2D)             (None, 14, 14, 64)        51264

 pool_2 (AveragePooling2D)   (None, 7, 7, 64)          0

 conv_3 (Conv2D)             (None, 7, 7, 64)          102464

 pool_3 (AveragePooling2D)   (None, 3, 3, 64)          0

 conv_4 (Conv2D)             (None, 3, 3, 32)          51232

 pool_4 (AveragePooling2D)   (None, 1, 1, 32)          0

 flatten_1 (Flatten)         (None, 32)                0

 fc_1 (Dense)                (None, 1024)              33792

 fc_2 (Dense)                (None, 10)                10250

=================================================================
Total params: 249834 (975.91 KB)
Trainable params: 249834 (975.91 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

In [34]:
```
######################
# fit your second model
######################
history = model.fit(X_train, y_train, epochs=3, validation_data=(X_valid, y
```

```
Epoch 1/3
1500/1500 [==============================] - 171s 113ms/step - loss: 0.66
54 - accuracy: 0.7458 - val_loss: 0.4917 - val_accuracy: 0.8153
Epoch 2/3
1500/1500 [==============================] - 159s 106ms/step - loss: 0.39
90 - accuracy: 0.8522 - val_loss: 0.3612 - val_accuracy: 0.8673
Epoch 3/3
1500/1500 [==============================] - 158s 105ms/step - loss: 0.33
07 - accuracy: 0.8756 - val_loss: 0.2996 - val_accuracy: 0.8885
```

In [35]:
```
##########################################################################
# evaluate your second model and and plot your training curve and show clas
##########################################################################
hist = history.history
x_arr = np.arange(len(hist['loss'])) + 1

fig = plt.figure(figsize=(12, 4))
ax = fig.add_subplot(1, 2, 1)
ax.plot(x_arr, hist['loss'], '-o', label='Train loss')
ax.plot(x_arr, hist['val_loss'], '--<', label='Validation loss')
ax.set_xlabel('Epoch', size=15)
ax.set_ylabel('Loss', size=15)
ax.legend(fontsize=15)
ax = fig.add_subplot(1, 2, 2)
ax.plot(x_arr, hist['accuracy'], '-o', label='Train acc.')
ax.plot(x_arr, hist['val_accuracy'], '--<', label='Validation acc.')
ax.legend(fontsize=15)
ax.set_xlabel('Epoch', size=15)
ax.set_ylabel('Accuracy', size=15)


plt.show()
```



In [36]:
```
test_results = model.evaluate(X_test , y_test)
print(f"Test Accuracy is {test_results[1]*100}")
```

```
313/313 [==============================] - 10s 30ms/step - loss: 0.2868 -
accuracy: 0.8899
Test Accuracy is 88.99000287055969
```

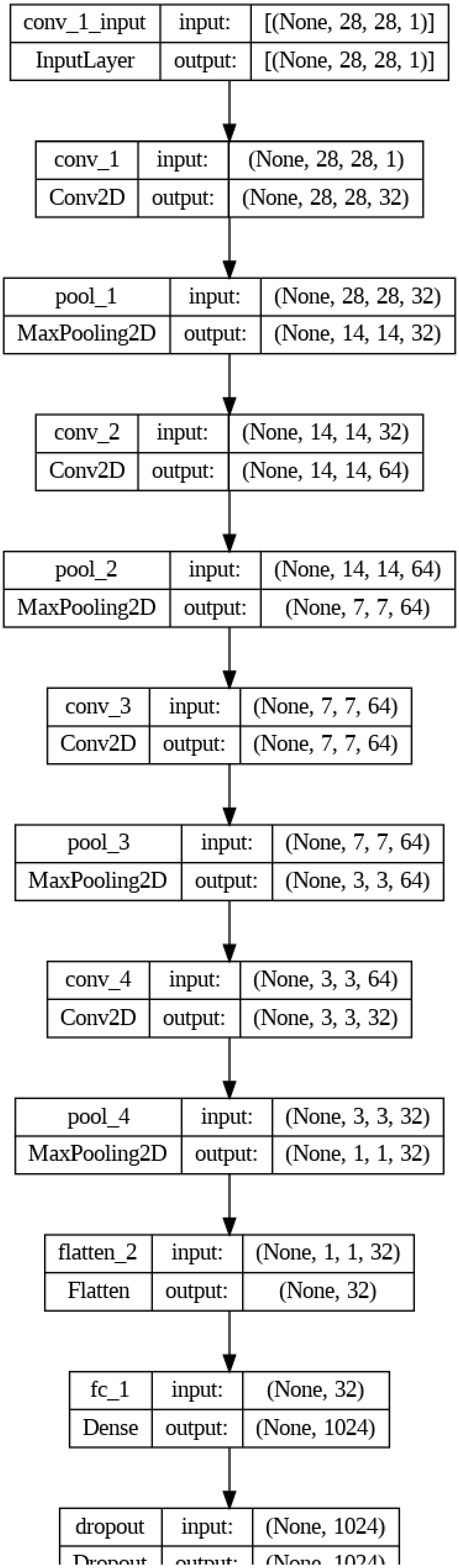
Third model

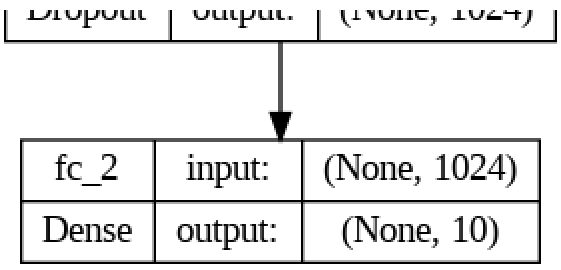
In [37]:
```
##########################
# design your third model
##########################
model = tf.keras.Sequential()
model.add(tf.keras.layers.Conv2D(filters=32, kernel_size=(5, 5),strides=(1,
model.add(tf.keras.layers.MaxPool2D(pool_size=(2, 2), name='pool_1'))
model.add(tf.keras.layers.Conv2D(filters=64, kernel_size=(5, 5),strides=(1,
model.add(tf.keras.layers.MaxPool2D(pool_size=(2, 2), name='pool_2'))
model.add(tf.keras.layers.Conv2D(filters=64, kernel_size=(5, 5),strides=(1,
model.add(tf.keras.layers.MaxPool2D(pool_size=(2, 2), name='pool_3'))
model.add(tf.keras.layers.Conv2D(filters=32, kernel_size=(5, 5),strides=(1,
model.add(tf.keras.layers.MaxPool2D(pool_size=(2, 2), name='pool_4'))
model.add(tf.keras.layers.Flatten())
model.add(tf.keras.layers.Dense(units=1024, name='fc_1', activation='relu')
model.add(tf.keras.layers.Dropout(rate = 0.5))
model.add(tf.keras.layers.Dense(units=10, name='fc_2',activation='softmax')
model.build(input_shape=(None, 28, 28, 1))
```

In [38]:

```
tf.keras.utils.plot_model(model, show_shapes=True, show_layer_names=True)
```

```
Out[38]:
```


conv_1_input
InputLayer
input:
output:
[(None, 28, 28, 1)]
[(None, 28, 28, 1)]
conv_1
Conv2D
input:
output:
(None, 28, 28, 1)
(None, 28, 28, 32)
pool_1
MaxPooling2D
input:
output:
(None, 28, 28, 32)
(None, 14, 14, 32)
conv_2
Conv2D
input:
output:
(None, 14, 14, 32)
(None, 14, 14, 64)
pool_2
MaxPooling2D
input:
output:
(None, 14, 14, 64)
(None, 7, 7, 64)
conv_3
Conv2D
input:
output:
(None, 7, 7, 64)
(None, 7, 7, 64)
pool_3
MaxPooling2D
input:
output:
(None, 7, 7, 64)
(None, 3, 3, 64)
conv_4
Conv2D
input:
output:
(None, 3, 3, 64)
(None, 3, 3, 32)
pool_4
MaxPooling2D
input:
output:
(None, 3, 3, 32)
(None, 1, 1, 32)
flatten_2
Flatten
input:
output:
(None, 1, 1, 32)
(None, 32)
fc_1
Dense
input:
output:
(None, 32)
(None, 1024)
dropout
input:
(None, 1024)



In [39]:
```
############################
# compile your first model
###########################
model.compile(optimizer=tf.keras.optimizers.Adam(),loss=tf.keras.losses.Spa
```

In [40]:
```
##########################
# get summary of your model
##########################
model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv_1 (Conv2D)             (None, 28, 28, 32)        832

 pool_1 (MaxPooling2D)       (None, 14, 14, 32)        0

 conv_2 (Conv2D)             (None, 14, 14, 64)        51264

 pool_2 (MaxPooling2D)       (None, 7, 7, 64)          0

 conv_3 (Conv2D)             (None, 7, 7, 64)          102464

 pool_3 (MaxPooling2D)       (None, 3, 3, 64)          0

 conv_4 (Conv2D)             (None, 3, 3, 32)          51232

 pool_4 (MaxPooling2D)       (None, 1, 1, 32)          0

 flatten_2 (Flatten)         (None, 32)                0

 fc_1 (Dense)                (None, 1024)              33792

 dropout (Dropout)           (None, 1024)              0

 fc_2 (Dense)                (None, 10)                10250

=================================================================
Total params: 249834 (975.91 KB)
Trainable params: 249834 (975.91 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

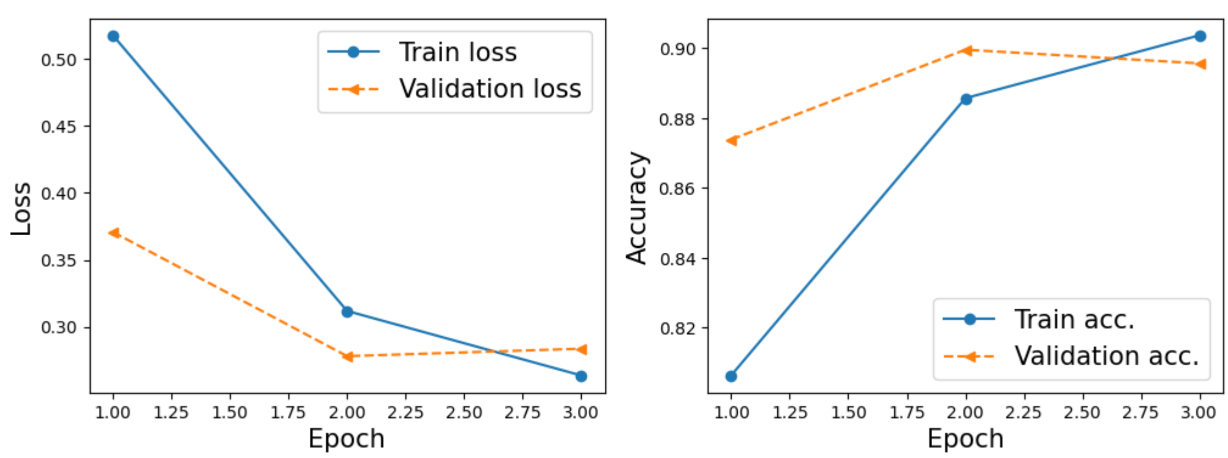
In [41]:

```
#######################
# fit your third model
#######################
history = model.fit(X_train, y_train, epochs=3, validation_data=(X_valid, y
```

```
Epoch 1/3

/usr/local/lib/python3.10/dist-packages/keras/src/backend.py:5727: UserWa
rning: "`sparse_categorical_crossentropy` received `from_logits=True`, bu
t the `output` argument was produced by a Softmax activation and thus doe
s not represent logits. Was this intended?
  output, from_logits = _get_logits(

1500/1500 [==============================] - 170s 113ms/step - loss: 0.51
78 - accuracy: 0.8063 - val_loss: 0.3708 - val_accuracy: 0.8738
Epoch 2/3
1500/1500 [==============================] - 167s 111ms/step - loss: 0.31
18 - accuracy: 0.8857 - val_loss: 0.2780 - val_accuracy: 0.8996
Epoch 3/3
1500/1500 [==============================] - 177s 118ms/step - loss: 0.26
36 - accuracy: 0.9037 - val_loss: 0.2836 - val_accuracy: 0.8957
```

In [42]:

```
##########################################################################
# evaluate your third model and and plot your training curve and show class
##########################################################################
hist = history.history
x_arr = np.arange(len(hist['loss'])) + 1

fig = plt.figure(figsize=(12, 4))
ax = fig.add_subplot(1, 2, 1)
ax.plot(x_arr, hist['loss'], '-o', label='Train loss')
ax.plot(x_arr, hist['val_loss'], '--<', label='Validation loss')
ax.set_xlabel('Epoch', size=15)
ax.set_ylabel('Loss', size=15)
ax.legend(fontsize=15)
ax = fig.add_subplot(1, 2, 2)
ax.plot(x_arr, hist['accuracy'], '-o', label='Train acc.')
ax.plot(x_arr, hist['val_accuracy'], '--<', label='Validation acc.')
ax.legend(fontsize=15)
ax.set_xlabel('Epoch', size=15)
ax.set_ylabel('Accuracy', size=15)


plt.show()
```



In [43]:

```
test_results = model.evaluate(X_test , y_test)
print(f"Test Accuracy is {test_results[1]*100}")
```

```
313/313 [==============================] - 8s 26ms/step - loss: 0.2779 -
accuracy: 0.8973
Test Accuracy is 89.73000049591064
```