In [1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import itertools
import keras
from keras import layers
from keras import models
from keras import optimizers
from keras.datasets import mnist
from keras.utils import to_categorical, np_utils
from keras.models import Sequential
from keras.optimizers import RMSprop
from keras.layers import Dense,Dropout,Flatten,Conv2D,MaxPooling2D
from sklearn.metrics import confusion_matrix
```

```
D:\Anaconda3\lib\site-packages\h5py\__init__.py:36: FutureWarning: Conversion of the second argument of issubdtype from `float`
to `np.floating` is deprecated. In future, it will be treated as `np.float64 == np.dtype(float).type`.
  from ._conv import register_converters as _register_converters
Using TensorFlow backend.
```

In [2]:
```
# train/test趨勢圖
def show_train_history(history, train, validation, modeltype, num, epochs):
    plt.plot(history.history[train], linewidth=3)
    plt.plot(history.history[validation], linewidth=3)
    plt.title('Train History')
    my_x_ticks = np.arange(0,epochs,1)
    plt.xticks(my_x_ticks)
    plt.ylabel(train)
    plt.xlabel('Epoch')
    plt.legend(['Train', 'Validation'], loc='best')
    plt.grid(True)
    if train == 'acc':
        plt.savefig("image/MNIST_acc_model_" + modeltype + str(num) + ".jpg", dpi=300)
    if train == 'loss':
        plt.savefig("image/MNIST_loss_model_" + modeltype + str(num) + ".jpg", dpi=300)
    plt.show()
```

MLP

In [3]:
```
(x_train, y_train), (x_test, y_test) = mnist.load_data()

# 將每一幅影像都轉換為一個長向量，大小為28*28=784
x_train = x_train.reshape(60000, 784)
x_test = x_test.reshape(10000, 784)
x_train = x_train.astype('float32')
x_test = x_test.astype('float32')

# 將影像的畫素歸到0~1
x_train /= 255
x_test /= 255
print(x_train.shape[0], 'train samples')
print(x_test.shape[0], 'test samples')
```

```
60000 train samples
10000 test samples
```

In [4]:
```
# MLP Model 參數設定
modeltype = 'MLP'
optimizer = 'rmsprop'
batch_size = 128
num_classes = 10
epochs = 20
verbose = 1
```

In [5]:
```
# 將類別向量轉換為二進制矩陣
y_train = keras.utils.to_categorical(y_train, num_classes)
y_test = keras.utils.to_categorical(y_test, num_classes)
```

In [6]:
```
model = Sequential()
model.add(Dense(512, activation='relu', input_shape=(784,)))
model.add(Dropout(0.2))
model.add(Dense(512, activation='relu'))
model.add(Dropout(0.2))
model.add(Dense(num_classes, activation='softmax'))
model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_1 (Dense)              (None, 512)               401920
_________________________________________________________________
dropout_1 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_2 (Dense)              (None, 512)               262656
_________________________________________________________________
dropout_2 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_3 (Dense)              (None, 10)                5130
=================================================================
Total params: 669,706
Trainable params: 669,706
Non-trainable params: 0
_________________________________________________________________
```

In [7]:
```
model.compile(loss='categorical_crossentropy', optimizer=optimizer, metrics=['accuracy'])
train_history = model.fit(x_train, y_train, batch_size=batch_size, epochs=epochs, verbose=verbose, validation_data=(x_test, y
```

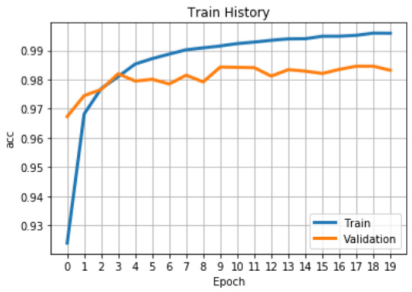
```
Train on 60000 samples, validate on 10000 samples
Epoch 1/20
60000/60000 [==============================] - 28s 466us/step - loss: 0.2442 - acc: 0.9239 - val_loss: 0.1118 - val_acc: 0.9673
Epoch 2/20
60000/60000 [==============================] - 5s 92us/step - loss: 0.1041 - acc: 0.9682 - val_loss: 0.0885 - val_acc: 0.9745
Epoch 3/20
60000/60000 [==============================] - 5s 91us/step - loss: 0.0758 - acc: 0.9769 - val_loss: 0.0791 - val_acc: 0.9766
Epoch 4/20
60000/60000 [==============================] - 5s 87us/step - loss: 0.0610 - acc: 0.9810 - val loss: 0.0696 - val acc: 0.9820
```

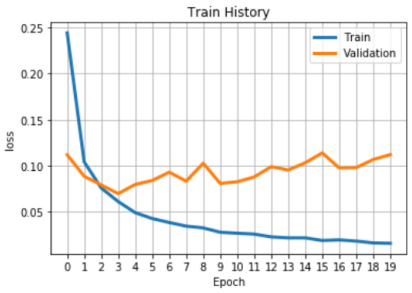
```
Epoch 5/20
60000/60000 [==============================] - 5s 91us/step - loss: 0.0490 - acc: 0.9853 - val_loss: 0.0796 - val_acc: 0.9795
Epoch 6/20
60000/60000 [==============================] - 6s 92us/step - loss: 0.0426 - acc: 0.9872 - val_loss: 0.0839 - val_acc: 0.9801
Epoch 7/20
60000/60000 [==============================] - 5s 88us/step - loss: 0.0383 - acc: 0.9888 - val_loss: 0.0929 - val_acc: 0.9785
Epoch 8/20
60000/60000 [==============================] - 5s 85us/step - loss: 0.0343 - acc: 0.9903 - val_loss: 0.0832 - val_acc: 0.9815
Epoch 9/20
60000/60000 [==============================] - 5s 89us/step - loss: 0.0324 - acc: 0.9909 - val_loss: 0.1027 - val_acc: 0.9792
Epoch 10/20
60000/60000 [==============================] - 5s 90us/step - loss: 0.0277 - acc: 0.9916 - val_loss: 0.0807 - val_acc: 0.9843
Epoch 11/20
60000/60000 [==============================] - 6s 93us/step - loss: 0.0266 - acc: 0.9924 - val_loss: 0.0825 - val_acc: 0.9842
Epoch 12/20
60000/60000 [==============================] - 5s 86us/step - loss: 0.0257 - acc: 0.9929 - val_loss: 0.0877 - val_acc: 0.9841
Epoch 13/20
60000/60000 [==============================] - 5s 88us/step - loss: 0.0226 - acc: 0.9935 - val_loss: 0.0989 - val_acc: 0.9812
Epoch 14/20
60000/60000 [==============================] - 5s 85us/step - loss: 0.0216 - acc: 0.9940 - val_loss: 0.0953 - val_acc: 0.9834
Epoch 15/20
60000/60000 [==============================] - 5s 87us/step - loss: 0.0216 - acc: 0.9940 - val_loss: 0.1032 - val_acc: 0.9829
Epoch 16/20
60000/60000 [==============================] - 5s 85us/step - loss: 0.0187 - acc: 0.9949 - val_loss: 0.1139 - val_acc: 0.9821
Epoch 17/20
60000/60000 [==============================] - 5s 90us/step - loss: 0.0194 - acc: 0.9949 - val_loss: 0.0975 - val_acc: 0.9835
Epoch 18/20
60000/60000 [==============================] - 5s 86us/step - loss: 0.0180 - acc: 0.9952 - val_loss: 0.0979 - val_acc: 0.9846
Epoch 19/20
60000/60000 [==============================] - 5s 89us/step - loss: 0.0161 - acc: 0.9960 - val_loss: 0.1067 - val_acc: 0.9846
Epoch 20/20
60000/60000 [==============================] - 6s 93us/step - loss: 0.0157 - acc: 0.9959 - val_loss: 0.1121 - val_acc: 0.9832
```

In [8]:

```
num = 1
score = model.evaluate(x_test, y_test, verbose=0)
show_train_history(train_history, 'acc', 'val_acc', modeltype, num, epochs)
show_train_history(train_history, 'loss', 'val_loss', modeltype, num, epochs)

df = pd.DataFrame()
metrics = ['Test loss','Test accuracy']
score = [score[0], score[1]]
df["metrics"] = metrics
df["score"] = score
df.set_index('metrics', inplace=True)
df
```





Out[8]:

	score
metrics	
Test loss	0.112051
Test accuracy	0.983200

CNN

In [9]:

```
np.random.seed(10)
(x_train, y_train), (x_test, y_test) = mnist.load_data()

x_train40 = x_train.reshape(x_train.shape[0], 28, 28, 1).astype('float32')
x_test40 = x_test.reshape(x_test.shape[0], 28, 28, 1).astype('float32')
print(x_train40.shape[0], 'train samples')
print(x_test40.shape[0], 'test samples')

x_train40_norm = x_train40 / 255
x_test40_norm = x_test40 /255

y_trainOneHot = np_utils.to_categorical(y_train)
y_testOneHot = np_utils.to_categorical(y_test)
```

```
60000 train samples
10000 test samples
```

CNN Model 1

In [10]:

```
# CNN Model 1 參數設定
modeltype = 'CNN'
optimizer = 'sgd'
batch_size = 64
epochs = 20
verbose = 1
```

In [11]:
```
model = Sequential()
model.add(Conv2D(16, (5,5), activation="relu", padding="same", data_format="channels_last", input_shape=(28,28,1)))
model.add(MaxPooling2D(pool_size=(2,2), data_format="channels_last"))
model.add(Conv2D(36, (5,5), activation="relu", padding="same", data_format="channels_last"))
model.add(MaxPooling2D(pool_size=(2,2), data_format="channels_last"))
model.add(Flatten())
model.add(Dense(128, activation="relu"))
model.add(Dropout(0.5))
model.add(Dense(10, activation="softmax"))
model.summary()
```

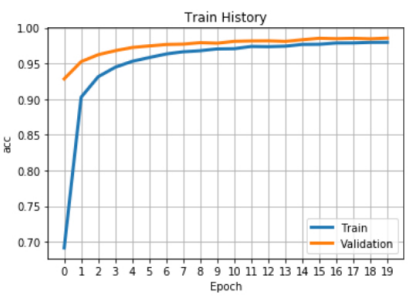
```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 28, 28, 16)        416
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 14, 14, 16)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 14, 14, 36)        14436
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 7, 7, 36)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 1764)              0
_________________________________________________________________
dense_4 (Dense)              (None, 128)               225920
_________________________________________________________________
dropout_3 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_5 (Dense)              (None, 10)                1290
=================================================================
Total params: 242,062
Trainable params: 242,062
Non-trainable params: 0
_________________________________________________________________
```

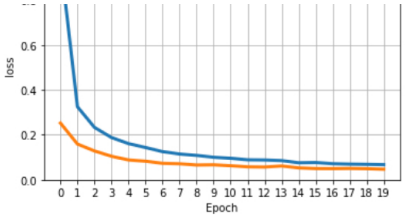
In [12]:
```
model.compile(loss='categorical_crossentropy', optimizer=optimizer, metrics=['accuracy'])
train_history = model.fit(x=x_train40_norm, y=y_trainOneHot, validation_split=0.2, epochs=epochs, batch_size=batch_size, verb
```

```
Train on 48000 samples, validate on 12000 samples
Epoch 1/20
48000/48000 [==============================] - 24s 491us/step - loss: 0.9806 - acc: 0.6916 - val_loss: 0.2525 - val_acc: 0.9285
Epoch 2/20
48000/48000 [==============================] - 16s 326us/step - loss: 0.3250 - acc: 0.9029 - val_loss: 0.1589 - val_acc: 0.9527
Epoch 3/20
48000/48000 [==============================] - 17s 358us/step - loss: 0.2331 - acc: 0.9315 - val_loss: 0.1283 - val_acc: 0.9624
Epoch 4/20
48000/48000 [==============================] - 17s 356us/step - loss: 0.1880 - acc: 0.9448 - val_loss: 0.1046 - val_acc: 0.9680
Epoch 5/20
48000/48000 [==============================] - 18s 366us/step - loss: 0.1610 - acc: 0.9531 - val_loss: 0.0882 - val_acc: 0.9725
s - loss: 0.
Epoch 6/20
48000/48000 [==============================] - 11s 227us/step - loss: 0.1436 - acc: 0.9584 - val_loss: 0.0827 - val_acc: 0.9747
Epoch 7/20
48000/48000 [==============================] - 12s 247us/step - loss: 0.1253 - acc: 0.9634 - val_loss: 0.0732 - val_acc: 0.9767
0s - loss: 0.1251 - acc: 0.963
Epoch 8/20
48000/48000 [==============================] - 11s 236us/step - loss: 0.1147 - acc: 0.9665 - val_loss: 0.0713 - val_acc: 0.9772
Epoch 9/20
48000/48000 [==============================] - 11s 237us/step - loss: 0.1083 - acc: 0.9680 - val_loss: 0.0657 - val_acc: 0.9792
Epoch 10/20
48000/48000 [==============================] - 12s 252us/step - loss: 0.1003 - acc: 0.9705 - val_loss: 0.0666 - val_acc: 0.9785
Epoch 11/20
48000/48000 [==============================] - 13s 264us/step - loss: 0.0957 - acc: 0.9709 - val_loss: 0.0626 - val_acc: 0.9811
Epoch 12/20
48000/48000 [==============================] - 12s 251us/step - loss: 0.0888 - acc: 0.9739 - val_loss: 0.0575 - val_acc: 0.9817
Epoch 13/20
48000/48000 [==============================] - 13s 261us/step - loss: 0.0881 - acc: 0.9736 - val_loss: 0.0567 - val_acc: 0.9818
Epoch 14/20
48000/48000 [==============================] - 12s 256us/step - loss: 0.0854 - acc: 0.9743 - val_loss: 0.0613 - val_acc: 0.9810
Epoch 15/20
48000/48000 [==============================] - 13s 268us/step - loss: 0.0758 - acc: 0.9768 - val_loss: 0.0529 - val_acc: 0.9833
Epoch 16/20
48000/48000 [==============================] - 14s 286us/step - loss: 0.0768 - acc: 0.9770 - val_loss: 0.0501 - val_acc: 0.9854
Epoch 17/20
48000/48000 [==============================] - 13s 271us/step - loss: 0.0715 - acc: 0.9788 - val_loss: 0.0497 - val_acc: 0.9848
Epoch 18/20
48000/48000 [==============================] - 12s 253us/step - loss: 0.0697 - acc: 0.9789 - val_loss: 0.0505 - val_acc: 0.9853
Epoch 19/20
48000/48000 [==============================] - 13s 277us/step - loss: 0.0686 - acc: 0.9797 - val_loss: 0.0494 - val_acc: 0.9847
- acc: 0.979
Epoch 20/20
48000/48000 [==============================] - 14s 282us/step - loss: 0.0672 - acc: 0.9798 - val_loss: 0.0469 - val_acc: 0.9857
```

In [13]:
```
num = 1
score = model.evaluate(x_test40_norm, y_testOneHot, verbose=0)
show_train_history(train_history, 'acc', 'val_acc', modeltype, num, epochs)
show_train_history(train_history, 'loss', 'val_loss', modeltype, num, epochs)

df = pd.DataFrame()
metrics = ['Test loss','Test accuracy']
score = [score[0], score[1]]
df["metrics"] = metrics
df["score"] = score
df.set_index('metrics', inplace=True)
df
```





Out[13]:

metrics	score
Test loss	0.035157
Test accuracy	0.988400

CNN Model 2

In [14]:
```
# CNN Model 2 參數設定
modeltype = 'CNN'
optimizer = 'rmsprop'
batch_size = 128
epochs = 20
num_classes = 10
verbose = 1
```

In [15]:
```
model = Sequential()
model.add(Conv2D(32, kernel_size=(3, 3), activation='relu', input_shape=(28, 28, 1)))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))
model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_3 (Conv2D)            (None, 26, 26, 32)        320
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 24, 24, 64)        18496
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 12, 12, 64)        0
_________________________________________________________________
dropout_4 (Dropout)          (None, 12, 12, 64)        0
_________________________________________________________________
flatten_2 (Flatten)          (None, 9216)              0
_________________________________________________________________
dense_6 (Dense)              (None, 128)               1179776
_________________________________________________________________
dropout_5 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_7 (Dense)              (None, 10)                1290
=================================================================
Total params: 1,199,882
Trainable params: 1,199,882
Non-trainable params: 0
_________________________________________________________________
```

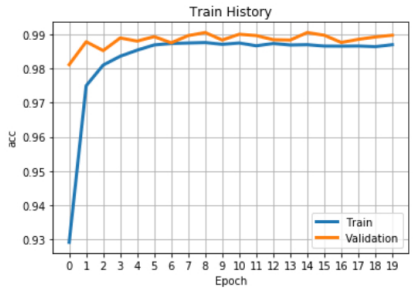
In [16]:
```
model.compile(loss='categorical_crossentropy', optimizer=optimizer, metrics=['accuracy'])
train_history = model.fit(x=x_train40_norm, y=y_trainOneHot, validation_split=0.2, epochs=epochs, batch_size=batch_size, verb
```

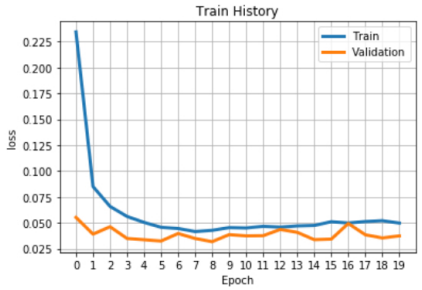
```
Train on 60000 samples, validate on 10000 samples
Epoch 1/20
60000/60000 [==============================] - 23s 389us/step - loss: 0.2344 - acc: 0.9291 - val_loss: 0.0552 - val_acc: 0.9812
Epoch 2/20
60000/60000 [==============================] - 22s 366us/step - loss: 0.0850 - acc: 0.9750 - val_loss: 0.0390 - val_acc: 0.9879
Epoch 3/20
60000/60000 [==============================] - 21s 355us/step - loss: 0.0658 - acc: 0.9811 - val_loss: 0.0462 - val_acc: 0.9853
Epoch 4/20
60000/60000 [==============================] - 21s 355us/step - loss: 0.0561 - acc: 0.9836 - val_loss: 0.0348 - val_acc: 0.9890
Epoch 5/20
60000/60000 [==============================] - 20s 335us/step - loss: 0.0504 - acc: 0.9854 - val_loss: 0.0336 - val_acc: 0.9881
Epoch 6/20
60000/60000 [==============================] - 20s 332us/step - loss: 0.0456 - acc: 0.9870 - val_loss: 0.0324 - val_acc: 0.9894
Epoch 7/20
60000/60000 [==============================] - 20s 329us/step - loss: 0.0445 - acc: 0.9874 - val_loss: 0.0396 - val_acc: 0.9876
Epoch 8/20
60000/60000 [==============================] - 20s 337us/step - loss: 0.0415 - acc: 0.9875 - val_loss: 0.0348 - val_acc: 0.9897
Epoch 9/20
60000/60000 [==============================] - 20s 331us/step - loss: 0.0427 - acc: 0.9877 - val_loss: 0.0318 - val_acc: 0.9906
Epoch 10/20
60000/60000 [==============================] - 21s 347us/step - loss: 0.0453 - acc: 0.9871 - val_loss: 0.0386 - val_acc: 0.9884
Epoch 11/20
60000/60000 [==============================] - 19s 311us/step - loss: 0.0450 - acc: 0.9875 - val_loss: 0.0374 - val_acc: 0.9901
Epoch 12/20
60000/60000 [==============================] - 19s 312us/step - loss: 0.0466 - acc: 0.9867 - val_loss: 0.0376 - val_acc: 0.9897
Epoch 13/20
60000/60000 [==============================] - 19s 315us/step - loss: 0.0458 - acc: 0.9874 - val_loss: 0.0435 - val_acc: 0.9885
Epoch 14/20
60000/60000 [==============================] - 19s 309us/step - loss: 0.0470 - acc: 0.9869 - val_loss: 0.0408 - val_acc: 0.9884
Epoch 15/20
60000/60000 [==============================] - 19s 311us/step - loss: 0.0474 - acc: 0.9870 - val_loss: 0.0337 - val_acc: 0.9906
Epoch 16/20
60000/60000 [==============================] - 18s 307us/step - loss: 0.0510 - acc: 0.9866 - val_loss: 0.0342 - val_acc: 0.9898
Epoch 17/20
60000/60000 [==============================] - 19s 310us/step - loss: 0.0498 - acc: 0.9866 - val_loss: 0.0493 - val_acc: 0.9877
Epoch 18/20
60000/60000 [==============================] - 18s 307us/step - loss: 0.0512 - acc: 0.9867 - val_loss: 0.0384 - val_acc: 0.9886
Epoch 19/20
60000/60000 [==============================] - 19s 315us/step - loss: 0.0521 - acc: 0.9865 - val_loss: 0.0354 - val_acc: 0.9893
Epoch 20/20
60000/60000 [==============================] - 18s 303us/step - loss: 0.0497 - acc: 0.9870 - val_loss: 0.0373 - val_acc: 0.9898
```

In [17]:
```
num = 2
score = model.evaluate(x_test40_norm, y_testOneHot, verbose=0)
show_train_history(train_history, 'acc', 'val_acc', modeltype, num, epochs)
show_train_history(train_history, 'loss', 'val_loss', modeltype, num, epochs)

```

```
df = pd.DataFrame()
metrics = ['Test loss','Test accuracy']
score = [score[0], score[1]]
df["metrics"] = metrics
df["score"] = score
df.set_index('metrics', inplace=True)
df
```





Out[17]:

	score
metrics	
Test loss	0.037317
Test accuracy	0.989800

CNN Model 3

In [18]:
```
# CNN Model 3 參數設定
modeltype = 'CNN'
optimizer = 'rmsprop'
batch_size = 128
epochs = 20
verbose = 1
```

In [19]:
```
model = models.Sequential()
model.add(layers.Conv2D(32, (3, 3), activation='relu', input_shape=(28, 28, 1))) # 加入 Covn2d 層 Conv2D(過濾器數量,過濾器長寬)
model.add(layers.MaxPooling2D((2, 2)))
model.add(layers.Conv2D(64, (3, 3), activation='relu'))
model.add(layers.MaxPooling2D((2, 2)))
model.add(layers.Conv2D(64, (3, 3), activation='relu'))
model.add(Flatten())  # 建立平坦層
model.add(Dense(128, activation='relu'))  # 建立 Hidden Layer
model.add(Dropout(0.5))
model.add(Dense(10, activation='softmax'))  # 建立輸出層
model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_5 (Conv2D)            (None, 26, 26, 32)        320
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 13, 13, 32)        0
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 11, 11, 64)        18496
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 5, 5, 64)          0
_________________________________________________________________
conv2d_7 (Conv2D)            (None, 3, 3, 64)          36928
_________________________________________________________________
flatten_3 (Flatten)          (None, 576)               0
_________________________________________________________________
dense_8 (Dense)              (None, 128)               73856
_________________________________________________________________
dropout_6 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_9 (Dense)              (None, 10)                1290
=================================================================
Total params: 130,890
Trainable params: 130,890
Non-trainable params: 0
_________________________________________________________________
```

In [20]:
```
model.compile(loss='categorical_crossentropy', optimizer=optimizer, metrics=['accuracy'])
train_history = model.fit(x=x_train40_norm, y=y_trainOneHot, validation_split=0.2, epochs=epochs, batch_size=batch_size, verb
```

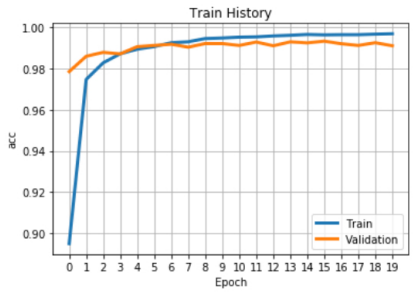
```
Train on 48000 samples, validate on 12000 samples
Epoch 1/20
48000/48000 [==============================] - 12s 259us/step - loss: 0.3379 - acc: 0.8951 - val_loss: 0.0717 - val_acc: 0.9784
Epoch 2/20
48000/48000 [==============================] - 8s 169us/step - loss: 0.0859 - acc: 0.9746 - val_loss: 0.0492 - val_acc: 0.9858
Epoch 3/20
48000/48000 [==============================] - 8s 161us/step - loss: 0.0583 - acc: 0.9827 - val_loss: 0.0421 - val_acc: 0.9877
Epoch 4/20
48000/48000 [==============================] - 8s 174us/step - loss: 0.0445 - acc: 0.9870 - val_loss: 0.0440 - val_acc: 0.9870
Epoch 5/20
48000/48000 [==============================] - 8s 160us/step - loss: 0.0364 - acc: 0.9893 - val_loss: 0.0380 - val_acc: 0.9905
Epoch 6/20
48000/48000 [==============================] - 8s 168us/step - loss: 0.0316 - acc: 0.9905 - val_loss: 0.0334 - val_acc: 0.9911
Epoch 7/20
48000/48000 [==============================] - 7s 156us/step - loss: 0.0258 - acc: 0.9924 - val_loss: 0.0341 - val_acc: 0.9917
Epoch 8/20
48000/48000 [==============================] - 7s 154us/step - loss: 0.0230 - acc: 0.9929 - val_loss: 0.0352 - val_acc: 0.9902
```

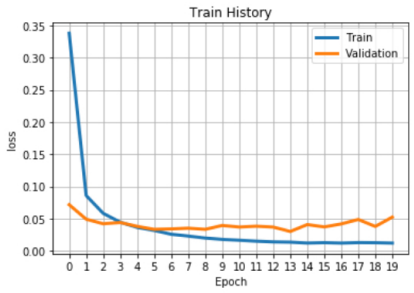
```
Epoch 9/20
48000/48000 [==============================] - 7s 155us/step - loss: 0.0199 - acc: 0.9944 - val_loss: 0.0334 - val_acc: 0.9920
Epoch 10/20
48000/48000 [==============================] - 8s 165us/step - loss: 0.0178 - acc: 0.9947 - val_loss: 0.0394 - val_acc: 0.9920
Epoch 11/20
48000/48000 [==============================] - 8s 172us/step - loss: 0.0165 - acc: 0.9951 - val_loss: 0.0370 - val_acc: 0.9911
Epoch 12/20
48000/48000 [==============================] - 8s 168us/step - loss: 0.0150 - acc: 0.9952 - val_loss: 0.0382 - val_acc: 0.9927
Epoch 13/20
48000/48000 [==============================] - 8s 168us/step - loss: 0.0140 - acc: 0.9957 - val_loss: 0.0369 - val_acc: 0.9909
Epoch 14/20
48000/48000 [==============================] - 8s 166us/step - loss: 0.0136 - acc: 0.9960 - val_loss: 0.0301 - val_acc: 0.9928
Epoch 15/20
48000/48000 [==============================] - 8s 175us/step - loss: 0.0122 - acc: 0.9964 - val_loss: 0.0408 - val_acc: 0.9923
Epoch 16/20
48000/48000 [==============================] - 9s 188us/step - loss: 0.0128 - acc: 0.9962 - val_loss: 0.0371 - val_acc: 0.9932
Epoch 17/20
48000/48000 [==============================] - 9s 181us/step - loss: 0.0121 - acc: 0.9963 - val_loss: 0.0419 - val_acc: 0.9919
Epoch 18/20
48000/48000 [==============================] - 10s 204us/step - loss: 0.0129 - acc: 0.9963 - val_loss: 0.0488 - val_acc: 0.9911
Epoch 19/20
48000/48000 [==============================] - 10s 201us/step - loss: 0.0127 - acc: 0.9965 - val_loss: 0.0379 - val_acc: 0.9924
Epoch 20/20
48000/48000 [==============================] - 9s 186us/step - loss: 0.0121 - acc: 0.9968 - val_loss: 0.0524 - val_acc: 0.9909
```

In [21]:

```
num = 3
score = model.evaluate(x_train40_norm, y_trainOneHot, verbose=0)
show_train_history(train_history, 'acc', 'val_acc', modeltype, num, epochs)
show_train_history(train_history, 'loss', 'val_loss', modeltype, num, epochs)

df = pd.DataFrame()
metrics = ['Test loss','Test accuracy']
score = [score[0], score[1]]
df["metrics"] = metrics
df["score"] = score
df.set_index('metrics', inplace=True)
df
```





Out[21]:

metrics	score
Test loss	0.012839
Test accuracy	0.997400

In [ ]:

```
1
```