```
import pandas as pd
import numpy as np
from keras.layers import Conv2D , MaxPooling2D , Dense, Flatten , Input , Dropout
from keras.models import Sequential , Model
import keras
import tensorflow as tf
from PIL import Image
from keras.models import model_from_json
import os
from keras.preprocessing.image import ImageDataGenerator
from keras import utils as np_utils
```

```
df = pd.read_csv('train.csv')
images = []
Y = np.asarray(df['label'])
Y = np.reshape(Y, (Y.shape[0], 1))
print(Y.shape)
df = df.drop(['label'], axis=1)

images = df.to_numpy()
images = np.reshape(images, (images.shape[0], 28, 28, 1))
X = images
del images
X = X/255.0
print(X.shape)
```

```
(42000, 1)
(42000, 28, 28, 1)
```

```
Y = np_utils.to_categorical(Y)
print(Y)
```

```
[[0. 1. 0. ... 0. 0. 0.]
 [1. 0. 0. ... 0. 0. 0.]
 [0. 1. 0. ... 0. 0. 0.]
 ...
 [0. 0. 0. ... 1. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 1.]]
```

```
model = Sequential()
model.add(Conv2D(30, (5, 5), input_shape=(28, 28, 1), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Conv2D(15, (3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.2))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dense(50, activation='relu'))
model.add(Dense(10, activation='softmax'))
# Compile model
model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy'])
model.fit(X , Y , batch_size = 128 , epochs = 100 , validation_split = 0)
print(model.summary())
```

```
Epoch 1/100
42000/42000 [==============================] - 5s 119us/step - loss: 0.3748 - acc: 0.8837
Epoch 2/100
42000/42000 [==============================] - 4s 92us/step - loss: 0.0938 - acc: 0.9712
Epoch 3/100
42000/42000 [==============================] - 4s 92us/step - loss: 0.0691 - acc: 0.9784
Epoch 4/100
42000/42000 [==============================] - 4s 94us/step - loss: 0.0557 - acc: 0.9828
Epoch 5/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0467 - acc: 0.9854
Epoch 6/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0438 - acc: 0.9855
Epoch 7/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0370 - acc: 0.9883
Epoch 8/100
42000/42000 [==============================] - 4s 92us/step - loss: 0.0348 - acc: 0.9886
Epoch 9/100
42000/42000 [==============================] - 4s 93us/step - loss: 0.0311 - acc: 0.9897
Epoch 10/100
42000/42000 [==============================] - 4s 92us/step - loss: 0.0292 - acc: 0.9907
Epoch 11/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0271 - acc: 0.9909
Epoch 12/100
42000/42000 [==============================] - 4s 92us/step - loss: 0.0262 - acc: 0.9912
Epoch 13/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0223 - acc: 0.9925
Epoch 14/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0200 - acc: 0.9938
Epoch 15/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0204 - acc: 0.9933
Epoch 16/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0204 - acc: 0.9930
Epoch 17/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0173 - acc: 0.9945
Epoch 18/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0184 - acc: 0.9937
Epoch 19/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0164 - acc: 0.9946
Epoch 20/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0147 - acc: 0.9949
Epoch 21/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0139 - acc: 0.9950
Epoch 22/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0144 - acc: 0.9950
Epoch 23/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0144 - acc: 0.9952
Epoch 24/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0119 - acc: 0.9962
Epoch 25/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0126 - acc: 0.9956
Epoch 26/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0144 - acc: 0.9952
Epoch 27/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0107 - acc: 0.9963
Epoch 28/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0131 - acc: 0.9955
Epoch 29/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0104 - acc: 0.9963
Epoch 30/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0114 - acc: 0.9963
Epoch 31/100
42000/42000 [==============================] - 4s 88us/step - loss: 0.0094 - acc: 0.9969
Epoch 32/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0115 - acc: 0.9962
Epoch 33/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0101 - acc: 0.9969
Epoch 34/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0089 - acc: 0.9972
Epoch 35/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0097 - acc: 0.9966
Epoch 36/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0100 - acc: 0.9967
Epoch 37/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0079 - acc: 0.9974
Epoch 38/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0090 - acc: 0.9969
Epoch 39/100
42000/42000 [==============================] - 4s 92us/step - loss: 0.0102 - acc: 0.9965
Epoch 40/100
42000/42000 [==============================] - 4s 92us/step - loss: 0.0090 - acc: 0.9971
Epoch 41/100
42000/42000 [==============================] - 4s 92us/step - loss: 0.0076 - acc: 0.9976
Epoch 42/100
42000/42000 [==============================] - 4s 88us/step - loss: 0.0077 - acc: 0.9974
Epoch 43/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0083 - acc: 0.9971
Epoch 44/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0067 - acc: 0.9979
Epoch 45/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0067 - acc: 0.9979
Epoch 46/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0088 - acc: 0.9970
Epoch 47/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0086 - acc: 0.9974
Epoch 48/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0066 - acc: 0.9979
Epoch 49/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0086 - acc: 0.9972
Epoch 50/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0070 - acc: 0.9978
Epoch 51/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0080 - acc: 0.9973
Epoch 52/100
42000/42000 [==============================] - 4s 93us/step - loss: 0.0059 - acc: 0.9981
Epoch 53/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0087 - acc: 0.9972
Epoch 54/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0073 - acc: 0.9975
Epoch 55/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0066 - acc: 0.9979
Epoch 56/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0060 - acc: 0.9980
Epoch 57/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0073 - acc: 0.9977
```

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42000/42000 [==============================] - 4s 90us/step - loss: 0.0073 - acc: 0.9977
Epoch 58/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0082 - acc: 0.9975
Epoch 59/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0048 - acc: 0.9985
Epoch 60/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0074 - acc: 0.9975
Epoch 61/100
42000/42000 [==============================] - 4s 88us/step - loss: 0.0067 - acc: 0.9979
Epoch 62/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0051 - acc: 0.9983
Epoch 63/100
42000/42000 [==============================] - 4s 93us/step - loss: 0.0056 - acc: 0.9982
Epoch 64/100
42000/42000 [==============================] - 4s 92us/step - loss: 0.0070 - acc: 0.9979
Epoch 65/100
42000/42000 [==============================] - 4s 93us/step - loss: 0.0074 - acc: 0.9978
Epoch 66/100
42000/42000 [==============================] - 4s 95us/step - loss: 0.0041 - acc: 0.9987
Epoch 67/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0047 - acc: 0.9987
Epoch 68/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0088 - acc: 0.9972
Epoch 69/100
42000/42000 [==============================] - 4s 88us/step - loss: 0.0061 - acc: 0.9980
Epoch 70/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0058 - acc: 0.9983
Epoch 71/100
42000/42000 [==============================] - 4s 92us/step - loss: 0.0046 - acc: 0.9986
Epoch 72/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0061 - acc: 0.9982
Epoch 73/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0079 - acc: 0.9974
Epoch 74/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0059 - acc: 0.9982
Epoch 75/100
42000/42000 [==============================] - 4s 87us/step - loss: 0.0044 - acc: 0.9987
Epoch 76/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0052 - acc: 0.9982
Epoch 77/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0062 - acc: 0.9981
Epoch 78/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0046 - acc: 0.9987
Epoch 79/100
42000/42000 [==============================] - 4s 92us/step - loss: 0.0037 - acc: 0.9990
Epoch 80/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0075 - acc: 0.9980
Epoch 81/100
42000/42000 [==============================] - 4s 88us/step - loss: 0.0050 - acc: 0.9985
Epoch 82/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0044 - acc: 0.9986
Epoch 83/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0060 - acc: 0.9982
Epoch 84/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0066 - acc: 0.9981
Epoch 85/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0043 - acc: 0.9987
Epoch 86/100
42000/42000 [==============================] - 4s 88us/step - loss: 0.0049 - acc: 0.9987
Epoch 87/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0046 - acc: 0.9987
Epoch 88/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0058 - acc: 0.9984
Epoch 89/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0047 - acc: 0.9987
Epoch 90/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0053 - acc: 0.9985
Epoch 91/100
42000/42000 [==============================] - 4s 92us/step - loss: 0.0044 - acc: 0.9986
Epoch 92/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0049 - acc: 0.9986
Epoch 93/100
42000/42000 [==============================] - 4s 88us/step - loss: 0.0052 - acc: 0.9985
Epoch 94/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0044 - acc: 0.9986
Epoch 95/100
42000/42000 [==============================] - 4s 89us/step - loss: 0.0052 - acc: 0.9984
Epoch 96/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0057 - acc: 0.9982
Epoch 97/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0049 - acc: 0.9985
Epoch 98/100
42000/42000 [==============================] - 4s 91us/step - loss: 0.0040 - acc: 0.9988
Epoch 99/100
42000/42000 [==============================] - 4s 94us/step - loss: 0.0045 - acc: 0.9987
Epoch 100/100
42000/42000 [==============================] - 4s 90us/step - loss: 0.0046 - acc: 0.9986
Model: "sequential_16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_46 (Conv2D)           (None, 24, 24, 30)        780
_________________________________________________________________
max_pooling2d_29 (MaxPooling (None, 12, 12, 30)        0
_________________________________________________________________
conv2d_47 (Conv2D)           (None, 10, 10, 15)        4065
_________________________________________________________________
max_pooling2d_30 (MaxPooling (None, 5, 5, 15)          0
_________________________________________________________________
dropout_18 (Dropout)         (None, 5, 5, 15)          0
_________________________________________________________________
flatten_15 (Flatten)         (None, 375)               0
_________________________________________________________________
dense_34 (Dense)             (None, 128)               48128
_________________________________________________________________
dense_35 (Dense)             (None, 50)                6450
_________________________________________________________________
dense_36 (Dense)             (None, 10)                510
=================================================================
Total params: 59,933
Trainable params: 59,933
Non-trainable params: 0
_________________________________________________________________
None
```