

# CIAFR-10 image-classfication project

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Using **ResNet-50** model

About CIAFR-10 Datasets:

[Datasets](#)

[References](#)

## Import modules

```
1 #import required packages#
2 import pickle
3 import numpy as np
4 import keras
5 from keras.layers import Dense, Conv2D, BatchNormalization, Activation, Add,
  Input, Flatten, ZeroPadding2D, MaxPooling2D, AveragePooling2D
6 from keras.models import Model
7 from keras.utils import to_categorical
8 from keras.preprocessing.image import ImageDataGenerator
9
```

```
1 Using TensorFlow backend.
```

## Load Datasets

```
1 # If you have already downloaded the dataset and unpackaged it, make
  file_local true
2
3 file_local = True
4
5 #load dataset#
6 def unpickle(file):
7     with open(file, 'rb') as fo:
8         dict = pickle.load(fo, encoding='bytes')
9     return dict
10
11 def load_data():
12
13     #load train data
14     X_train = []
15     Y_train = []
16     for i in range(1,6):
17         train_batch = unpickle("data_batch_"+ str(i))
18         X_orig = train_batch[b"data"]
19         Y_orig = train_batch[b"labels"]
20         X_processed =
  X_orig.reshape((10000,3,32,32)).transpose(0,2,3,1).astype('float32')
21         Y_processed = to_categorical(np.array(Y_orig),10)
22         X_train.append(X_processed)
23         Y_train.append(Y_processed)
```

```

24     X_train = np.concatenate(X_train)
25     Y_train = np.concatenate(Y_train)
26
27     #load test data
28     test_batch = unpickle("test_batch")
29     X_orig = test_batch[b"data"]
30     Y_orig = test_batch[b"labels"]
31     X_test =
X_orig.reshape((10000,3,32,32)).transpose(0,2,3,1).astype('float32')
32     Y_test = to_categorical(np.array(Y_orig),10)
33
34     return X_train, Y_train, X_test, Y_test
35
36 if file_local :
37     X_train, Y_train, X_test, Y_test = load_data()
38
39 else :
40     (X_train, Y_train), (X_test, Y_test) =
keras.datasets.cifar10.load_data()
41     Y_train = to_categorical(np.array(Y_train),10)
42     Y_test = to_categorical(np.array(Y_test),10)
43
44
45 (M, n_H, n_W, n_C) = X_train.shape
46 input_shape = (n_H,n_W,n_C)
47
48
49 print ("data loading completed")
50 print ("number of training examples = " + str(X_train.shape[0]))
51 print ("number of test examples = " + str(X_test.shape[0]))
52 print ("X_train shape: " + str(X_train.shape))
53 print ("Y_train shape: " + str(Y_train.shape))
54 print ("X_test shape: " + str(X_test.shape))
55 print ("Y_test shape: " + str(Y_test.shape))
56
57

```

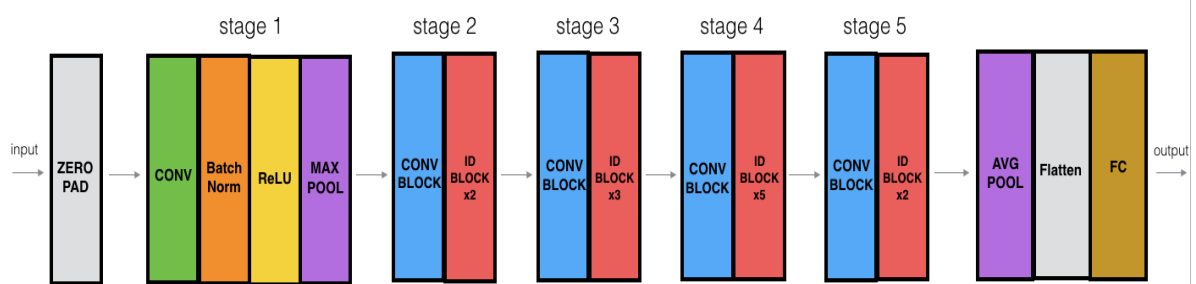
```

1  data loading completed
2  number of training examples = 50000
3  number of test examples = 10000
4  X_train shape: (50000, 32, 32, 3)
5  Y_train shape: (50000, 10)
6  X_test shape: (10000, 32, 32, 3)
7  Y_test shape: (10000, 10)

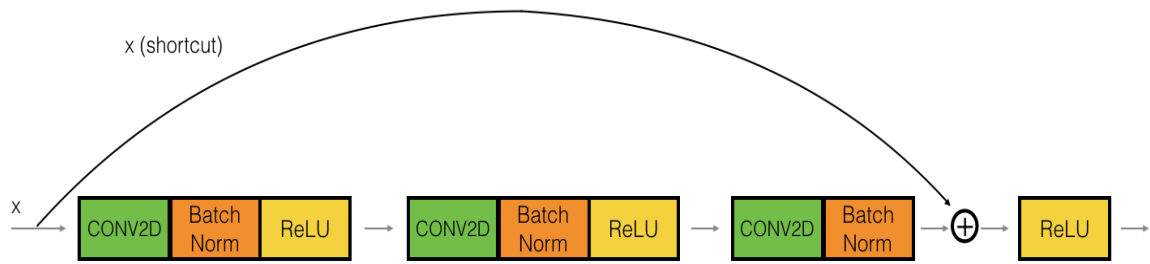
```

## Build ResNet-50 Model

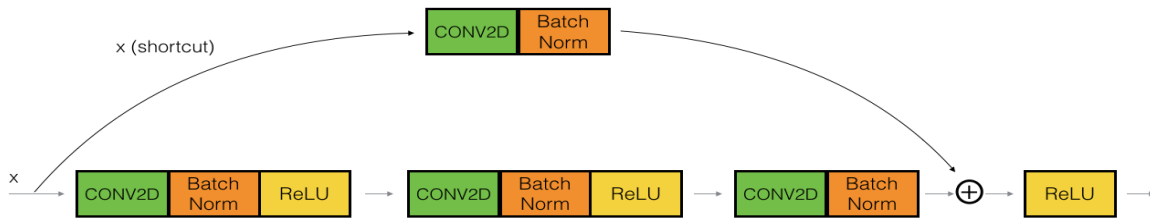
The following figure describes in detail the architecture of this network



And firstly We will impletemt convolutional residual block and identity residual block



Identity block



convolutional block

```

1  def id_block(x, f, kernel_channels ,activation = 'relu'):
2
3      x_shortcut = x
4
5      F1,F2,F3 = kernel_channels
6
7      x = Conv2D(filters = F1, kernel_size = (1, 1), strides = (1,1), padding
= 'valid')(x)
8      x = BatchNormalization(axis = 3)(x)
9      x = Activation(activation)(x)
10
11     x = Conv2D(filters = F2, kernel_size = (f, f), strides = (1,1), padding
= 'same')(x)
12     x = BatchNormalization(axis = 3)(x)
13     x = Activation(activation)(x)
14
15     x = Conv2D(filters = F3, kernel_size = (1, 1), strides = (1,1), padding
= 'valid')(x)
16     x = BatchNormalization(axis = 3)(x)
17
18     x = Add()([x,x_shortcut])
19     x = Activation(activation)(x)
20
21     return x
22
23
24  def conv_block(x, f, kernel_channels, strides, activation = 'relu'):
25
26     x_shortcut = x
27
28     F1,F2,F3 = kernel_channels
29

```

```

30     X = Conv2D(filters = F1, kernel_size = (1, 1), strides =
(strides,strides), padding = 'valid')(X)
31     X = BatchNormalization(axis = 3)(X)
32     X = Activation(activation)(X)
33
34     X = Conv2D(filters = F2, kernel_size = (f, f), strides = (1,1), padding
= 'same')(X)
35     X = BatchNormalization(axis = 3)(X)
36     X = Activation(activation)(X)
37
38     X = Conv2D(filters = F3, kernel_size = (1, 1), strides = (1,1), padding
= 'valid')(X)
39     X = BatchNormalization(axis = 3)(X)
40
41     X_shortcut = Conv2D(filters = F3, kernel_size = (1, 1), strides =
(strides,strides), padding = 'valid')(X_shortcut)
42     X_shortcut = BatchNormalization(axis = 3)(X_shortcut )
43
44     X = Add()([X,X_shortcut])
45     X = Activation(activation)(X)
46
47     return X
48
49
50
51 def ResNet50(Input_shape = (32, 32, 3), classes = 10):
52
53     X_input = Input(Input_shape)
54     X = ZeroPadding2D((1, 1))(X_input)
55
56     #stage 1
57     X = Conv2D(64, (3, 3), strides = (2, 2), padding = 'valid')(X)
58     X = BatchNormalization(axis = 3)(X)
59     X = Activation('relu')(X)
60     X = MaxPooling2D((3, 3), strides=(2, 2))(X)
61
62     #stage 2
63
64     X = conv_block(X , 3 , kernel_channels = [64, 64, 256], strides = 1)
65     X = id_block(X, 3, kernel_channels = [64, 64, 256])
66     X = id_block(X, 3, kernel_channels = [64, 64, 256])
67
68     #stage 3
69
70     X = conv_block(X, 3, kernel_channels = [128, 128, 512], strides = 2)
71     X = id_block(X, 3, kernel_channels = [128, 128, 512])
72     X = id_block(X, 3, kernel_channels = [128, 128, 512])
73     X = id_block(X, 3, kernel_channels = [128, 128, 512])
74
75     #stage 4
76
77     X = conv_block(X, 3, kernel_channels = [256, 256, 1024], strides = 2)
78     X = id_block(X, 3, kernel_channels = [256, 256, 1024])
79     X = id_block(X, 3, kernel_channels = [256, 256, 1024])
80     #X = id_block(X, 3, kernel_channels = [256, 256, 1024])
81     #X = id_block(X, 3, kernel_channels = [256, 256, 1024])
82     #X = id_block(X, 3, kernel_channels = [256, 256, 1024])
83

```

```

84     #stage 5
85
86     #X = conv_block(X, 3, kernel_channels = [512, 512, 2048], strides = 2)
87     #X = id_block(X, 3, kernel_channels = [512, 512, 2048])
88     #X = id_block(X, 3, kernel_channels = [512, 512, 2048])
89
90     X = AveragePooling2D(pool_size = (2, 2))(X)
91
92     X = Flatten()(X)
93     X = Dense(1024, activation='relu')(X)
94     X = Dense(classes, activation='softmax')(X)
95
96
97     model = Model(inputs = X_input, outputs = X, name='ResNet50')
98
99     return model
100
101

```

## Train the model

```

1  model = ResNet50(input_shape, classes= 10)
2  model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=
    ['accuracy'])
3
4  model.fit(X_train, Y_train, epochs = 200, batch_size = 256)
5
6  preds = model.evaluate(X_test, Y_test)
7  print ("Loss = " + str(preds[0]))
8  print ("Test Accuracy = " + str(preds[1]))

```

```

1  Epoch 1/200
2  50000/50000 [=====] - 25s 495us/step - loss:
    1.6875 - accuracy: 0.4302s - 1
3  Epoch 2/200
4  50000/50000 [=====] - 18s 370us/step - loss:
    1.0912 - accuracy: 0.6119
5  Epoch 3/200
6  50000/50000 [=====] - 19s 372us/step - loss:
    0.8783 - accuracy: 0.6904s - loss: 0.8779 - accu
7  Epoch 4/200
8  50000/50000 [=====] - 19s 375us/step - loss:
    0.7256 - accuracy: 0.7444
9  Epoch 5/200
10 50000/50000 [=====] - 19s 374us/step - loss:
    0.6015 - accuracy: 0.7894
11 Epoch 6/200
12 50000/50000 [=====] - 19s 375us/step - loss:
    0.5069 - accuracy: 0.8236
13 Epoch 7/200
14 50000/50000 [=====] - 19s 376us/step - loss:
    0.4209 - accuracy: 0.8531
15 Epoch 8/200
16 50000/50000 [=====] - 19s 378us/step - loss:
    0.3496 - accuracy: 0.8776
17 Epoch 9/200

```

```
18 50000/50000 [=====] - 19s 377us/step - loss:
    0.2966 - accuracy: 0.8969
19 Epoch 10/200
20 50000/50000 [=====] - 19s 377us/step - loss:
    0.2379 - accuracy: 0.9174
21 Epoch 11/200
22 50000/50000 [=====] - 19s 378us/step - loss:
    0.2019 - accuracy: 0.9297
23 Epoch 12/200
24 50000/50000 [=====] - 19s 378us/step - loss:
    0.1793 - accuracy: 0.9367s
25 Epoch 13/200
26 50000/50000 [=====] - 19s 382us/step - loss:
    0.1479 - accuracy: 0.9485
27 Epoch 14/200
28 50000/50000 [=====] - 19s 381us/step - loss:
    0.1376 - accuracy: 0.9523
29 Epoch 15/200
30 50000/50000 [=====] - 19s 382us/step - loss:
    0.1274 - accuracy: 0.9557
31 Epoch 16/200
32 50000/50000 [=====] - 19s 379us/step - loss:
    0.1254 - accuracy: 0.9549
33 Epoch 17/200
34 50000/50000 [=====] - 19s 380us/step - loss:
    0.1010 - accuracy: 0.9651
35 Epoch 18/200
36 50000/50000 [=====] - 19s 381us/step - loss:
    0.0926 - accuracy: 0.9676
37 Epoch 19/200
38 50000/50000 [=====] - 19s 380us/step - loss:
    0.0942 - accuracy: 0.9669
39 Epoch 20/200
40 50000/50000 [=====] - 19s 380us/step - loss:
    0.0794 - accuracy: 0.9731
41 Epoch 21/200
42 50000/50000 [=====] - 19s 381us/step - loss:
    0.0776 - accuracy: 0.9731
43 Epoch 22/200
44 50000/50000 [=====] - 19s 382us/step - loss:
    0.0768 - accuracy: 0.9735
45 Epoch 23/200
46 50000/50000 [=====] - 19s 381us/step - loss:
    0.0686 - accuracy: 0.9762
47 Epoch 24/200
48 50000/50000 [=====] - 19s 381us/step - loss:
    0.0819 - accuracy: 0.9723
49 Epoch 25/200
50 50000/50000 [=====] - 19s 380us/step - loss:
    0.0667 - accuracy: 0.9771
51 Epoch 26/200
52 50000/50000 [=====] - 19s 381us/step - loss:
    0.0549 - accuracy: 0.9808
53 Epoch 27/200
54 50000/50000 [=====] - 19s 383us/step - loss:
    0.0639 - accuracy: 0.9782
55 Epoch 28/200
```

```
56 50000/50000 [=====] - 19s 381us/step - loss:
    0.0679 - accuracy: 0.9771
57 Epoch 29/200
58 50000/50000 [=====] - 19s 384us/step - loss:
    0.0547 - accuracy: 0.9818
59 Epoch 30/200
60 50000/50000 [=====] - 19s 381us/step - loss:
    0.0655 - accuracy: 0.9770
61 Epoch 31/200
62 50000/50000 [=====] - 19s 382us/step - loss:
    0.0610 - accuracy: 0.9792
63 Epoch 32/200
64 50000/50000 [=====] - 19s 387us/step - loss:
    0.0516 - accuracy: 0.9830
65 Epoch 33/200
66 50000/50000 [=====] - 19s 378us/step - loss:
    0.0570 - accuracy: 0.9802
67 Epoch 34/200
68 50000/50000 [=====] - 19s 379us/step - loss:
    0.0501 - accuracy: 0.9830s - 1
69 Epoch 35/200
70 50000/50000 [=====] - 19s 379us/step - loss:
    0.0523 - accuracy: 0.9824
71 Epoch 36/200
72 50000/50000 [=====] - 19s 379us/step - loss:
    0.0494 - accuracy: 0.9828
73 Epoch 37/200
74 50000/50000 [=====] - 19s 379us/step - loss:
    0.0500 - accuracy: 0.9837
75 Epoch 38/200
76 50000/50000 [=====] - 19s 379us/step - loss:
    0.0468 - accuracy: 0.9839s - loss: 0.0465
77 Epoch 39/200
78 50000/50000 [=====] - 19s 378us/step - loss:
    0.0471 - accuracy: 0.9841
79 Epoch 40/200
80 50000/50000 [=====] - 19s 378us/step - loss:
    0.0447 - accuracy: 0.9845
81 Epoch 41/200
82 50000/50000 [=====] - 19s 379us/step - loss:
    0.0446 - accuracy: 0.9848
83 Epoch 42/200
84 50000/50000 [=====] - 19s 378us/step - loss:
    0.0490 - accuracy: 0.9836
85 Epoch 43/200
86 50000/50000 [=====] - 19s 380us/step - loss:
    0.0416 - accuracy: 0.9863
87 Epoch 44/200
88 50000/50000 [=====] - 19s 378us/step - loss:
    0.0371 - accuracy: 0.9876
89 Epoch 45/200
90 50000/50000 [=====] - 19s 378us/step - loss:
    0.0389 - accuracy: 0.9865
91 Epoch 46/200
92 50000/50000 [=====] - 19s 381us/step - loss:
    0.0375 - accuracy: 0.9870
93 Epoch 47/200
```

```
94 50000/50000 [=====] - 19s 379us/step - loss:
    0.0513 - accuracy: 0.9826
95 Epoch 48/200
96 50000/50000 [=====] - 19s 378us/step - loss:
    0.0331 - accuracy: 0.9883
97 Epoch 49/200
98 50000/50000 [=====] - 19s 380us/step - loss:
    0.0362 - accuracy: 0.9875
99 Epoch 50/200
100 50000/50000 [=====] - 19s 378us/step - loss:
    0.0420 - accuracy: 0.9859
101 Epoch 51/200
102 50000/50000 [=====] - 20s 398us/step - loss:
    0.0332 - accuracy: 0.9890s - loss: 0.0330 - accu
103 Epoch 52/200
104 50000/50000 [=====] - 19s 387us/step - loss:
    0.0265 - accuracy: 0.9916
105 Epoch 53/200
106 50000/50000 [=====] - 19s 385us/step - loss:
    0.0311 - accuracy: 0.9894
107 Epoch 54/200
108 50000/50000 [=====] - 19s 383us/step - loss:
    0.0374 - accuracy: 0.9876
109 Epoch 55/200
110 50000/50000 [=====] - 19s 383us/step - loss:
    0.0364 - accuracy: 0.9878
111 Epoch 56/200
112 50000/50000 [=====] - 19s 383us/step - loss:
    0.0361 - accuracy: 0.9880
113 Epoch 57/200
114 50000/50000 [=====] - 19s 383us/step - loss:
    0.0349 - accuracy: 0.9884
115 Epoch 58/200
116 50000/50000 [=====] - 19s 384us/step - loss:
    0.0307 - accuracy: 0.9896
117 Epoch 59/200
118 50000/50000 [=====] - 20s 394us/step - loss:
    0.0347 - accuracy: 0.9882
119 Epoch 60/200
120 50000/50000 [=====] - 19s 384us/step - loss:
    0.0260 - accuracy: 0.9911
121 Epoch 61/200
122 50000/50000 [=====] - 19s 383us/step - loss:
    0.0303 - accuracy: 0.9893
123 Epoch 62/200
124 50000/50000 [=====] - 20s 391us/step - loss:
    0.0334 - accuracy: 0.9891
125 Epoch 63/200
126 50000/50000 [=====] - 19s 382us/step - loss:
    0.0309 - accuracy: 0.9900
127 Epoch 64/200
128 50000/50000 [=====] - 19s 385us/step - loss:
    0.0252 - accuracy: 0.9916
129 Epoch 65/200
130 50000/50000 [=====] - 19s 384us/step - loss:
    0.0302 - accuracy: 0.9899
131 Epoch 66/200
```



```
132 50000/50000 [=====] - 20s 393us/step - loss:
    0.0306 - accuracy: 0.9895
133 Epoch 67/200
134 50000/50000 [=====] - 19s 383us/step - loss:
    0.0426 - accuracy: 0.9859
135 Epoch 68/200
136 50000/50000 [=====] - 19s 384us/step - loss:
    0.0229 - accuracy: 0.9921
137 Epoch 69/200
138 50000/50000 [=====] - 19s 383us/step - loss:
    0.0277 - accuracy: 0.9905
139 Epoch 70/200
140 50000/50000 [=====] - 19s 385us/step - loss:
    0.0207 - accuracy: 0.9927
141 Epoch 71/200
142 50000/50000 [=====] - 19s 386us/step - loss:
    0.0246 - accuracy: 0.9916
143 Epoch 72/200
144 50000/50000 [=====] - 20s 393us/step - loss:
    0.0282 - accuracy: 0.9905
145 Epoch 73/200
146 50000/50000 [=====] - 19s 385us/step - loss:
    0.0241 - accuracy: 0.9918s - loss: 0
147 Epoch 74/200
148 50000/50000 [=====] - 19s 385us/step - loss:
    0.0237 - accuracy: 0.9921
149 Epoch 75/200
150 50000/50000 [=====] - 19s 381us/step - loss:
    0.0288 - accuracy: 0.9900
151 Epoch 76/200
152 50000/50000 [=====] - 19s 382us/step - loss:
    0.0199 - accuracy: 0.9931
153 Epoch 77/200
154 50000/50000 [=====] - 19s 386us/step - loss:
    0.0246 - accuracy: 0.9919
155 Epoch 78/200
156 50000/50000 [=====] - 19s 380us/step - loss:
    0.0276 - accuracy: 0.9906
157 Epoch 79/200
158 50000/50000 [=====] - 20s 409us/step - loss:
    0.0176 - accuracy: 0.9944
159 Epoch 80/200
160 50000/50000 [=====] - 23s 456us/step - loss:
    0.0246 - accuracy: 0.9914
161 Epoch 81/200
162 50000/50000 [=====] - 21s 427us/step - loss:
    0.0213 - accuracy: 0.9925
163 Epoch 82/200
164 50000/50000 [=====] - 21s 420us/step - loss:
    0.0184 - accuracy: 0.9937
165 Epoch 83/200
166 50000/50000 [=====] - 21s 412us/step - loss:
    0.0209 - accuracy: 0.9936
167 Epoch 84/200
168 50000/50000 [=====] - 21s 412us/step - loss:
    0.0244 - accuracy: 0.9917
169 Epoch 85/200
```

```
170 50000/50000 [=====] - 20s 407us/step - loss:
    0.0230 - accuracy: 0.9919
171 Epoch 86/200
172 50000/50000 [=====] - 20s 405us/step - loss:
    0.0222 - accuracy: 0.9925
173 Epoch 87/200
174 50000/50000 [=====] - 21s 410us/step - loss:
    0.0166 - accuracy: 0.9945
175 Epoch 88/200
176 50000/50000 [=====] - 20s 408us/step - loss:
    0.0168 - accuracy: 0.9941
177 Epoch 89/200
178 50000/50000 [=====] - 21s 416us/step - loss:
    0.0285 - accuracy: 0.9906
179 Epoch 90/200
180 50000/50000 [=====] - 20s 398us/step - loss:
    0.0230 - accuracy: 0.9922s - loss: 0.0227 - accura
181 Epoch 91/200
182 50000/50000 [=====] - 19s 383us/step - loss:
    0.0137 - accuracy: 0.9955
183 Epoch 92/200
184 50000/50000 [=====] - 20s 410us/step - loss:
    0.0200 - accuracy: 0.9935
185 Epoch 93/200
186 50000/50000 [=====] - 21s 416us/step - loss:
    0.0197 - accuracy: 0.9933
187 Epoch 94/200
188 50000/50000 [=====] - 21s 417us/step - loss:
    0.0189 - accuracy: 0.9935
189 Epoch 95/200
190 50000/50000 [=====] - 22s 441us/step - loss:
    0.0222 - accuracy: 0.9929
191 Epoch 96/200
192 50000/50000 [=====] - 21s 419us/step - loss:
    0.0196 - accuracy: 0.9934s - loss: 0.0195 - accuracy:
193 Epoch 97/200
194 50000/50000 [=====] - 21s 428us/step - loss:
    0.0167 - accuracy: 0.9946
195 Epoch 98/200
196 50000/50000 [=====] - 21s 424us/step - loss:
    0.0205 - accuracy: 0.9933
197 Epoch 99/200
198 50000/50000 [=====] - 21s 422us/step - loss:
    0.0167 - accuracy: 0.9945
199 Epoch 100/200
200 50000/50000 [=====] - 21s 426us/step - loss:
    0.0247 - accuracy: 0.9918
201 Epoch 101/200
202 50000/50000 [=====] - 20s 409us/step - loss:
    0.0184 - accuracy: 0.9941
203 Epoch 102/200
204 50000/50000 [=====] - 21s 418us/step - loss:
    0.0146 - accuracy: 0.9954
205 Epoch 103/200
206 50000/50000 [=====] - 21s 422us/step - loss:
    0.0150 - accuracy: 0.9951
207 Epoch 104/200
```

```
208 50000/50000 [=====] - 20s 397us/step - loss:
    0.0158 - accuracy: 0.9948
209 Epoch 105/200
210 50000/50000 [=====] - 20s 398us/step - loss:
    0.0217 - accuracy: 0.9925
211 Epoch 106/200
212 50000/50000 [=====] - 20s 395us/step - loss:
    0.0140 - accuracy: 0.9952s - loss: 0.014
213 Epoch 107/200
214 50000/50000 [=====] - 19s 388us/step - loss:
    0.0132 - accuracy: 0.9955
215 Epoch 108/200
216 50000/50000 [=====] - 20s 394us/step - loss:
    0.0231 - accuracy: 0.9922
217 Epoch 109/200
218 50000/50000 [=====] - 20s 398us/step - loss:
    0.0130 - accuracy: 0.9958
219 Epoch 110/200
220 50000/50000 [=====] - 20s 399us/step - loss:
    0.0183 - accuracy: 0.9941
221 Epoch 111/200
222 50000/50000 [=====] - 20s 391us/step - loss:
    0.0172 - accuracy: 0.9940
223 Epoch 112/200
224 50000/50000 [=====] - 20s 396us/step - loss:
    0.0169 - accuracy: 0.9945
225 Epoch 113/200
226 50000/50000 [=====] - 20s 402us/step - loss:
    0.0124 - accuracy: 0.9961
227 Epoch 114/200
228 50000/50000 [=====] - 19s 385us/step - loss:
    0.0112 - accuracy: 0.9962
229 Epoch 115/200
230 50000/50000 [=====] - 19s 385us/step - loss:
    0.0205 - accuracy: 0.9933
231 Epoch 116/200
232 50000/50000 [=====] - 20s 399us/step - loss:
    0.0144 - accuracy: 0.9954
233 Epoch 117/200
234 50000/50000 [=====] - 20s 402us/step - loss:
    0.0143 - accuracy: 0.9952
235 Epoch 118/200
236 50000/50000 [=====] - 19s 390us/step - loss:
    0.0128 - accuracy: 0.9954
237 Epoch 119/200
238 50000/50000 [=====] - 20s 402us/step - loss:
    0.0228 - accuracy: 0.9925
239 Epoch 120/200
240 50000/50000 [=====] - 20s 405us/step - loss:
    0.0107 - accuracy: 0.9962
241 Epoch 121/200
242 50000/50000 [=====] - 20s 394us/step - loss:
    0.0145 - accuracy: 0.9955
243 Epoch 122/200
244 50000/50000 [=====] - 20s 394us/step - loss:
    0.0178 - accuracy: 0.9940
245 Epoch 123/200
```

```
246 50000/50000 [=====] - 19s 384us/step - loss:
    0.0161 - accuracy: 0.9948
247 Epoch 124/200
248 50000/50000 [=====] - 19s 386us/step - loss:
    0.0123 - accuracy: 0.9960
249 Epoch 125/200
250 50000/50000 [=====] - 20s 392us/step - loss:
    0.0145 - accuracy: 0.9949
251 Epoch 126/200
252 50000/50000 [=====] - 20s 400us/step - loss:
    0.0104 - accuracy: 0.9963
253 Epoch 127/200
254 50000/50000 [=====] - 20s 396us/step - loss:
    0.0170 - accuracy: 0.9943
255 Epoch 128/200
256 50000/50000 [=====] - 20s 394us/step - loss:
    0.0160 - accuracy: 0.9950
257 Epoch 129/200
258 50000/50000 [=====] - 19s 386us/step - loss:
    0.0192 - accuracy: 0.9937
259 Epoch 130/200
260 50000/50000 [=====] - 20s 395us/step - loss:
    0.0077 - accuracy: 0.9974
261 Epoch 131/200
262 50000/50000 [=====] - 20s 394us/step - loss:
    0.0041 - accuracy: 0.9985
263 Epoch 132/200
264 50000/50000 [=====] - 19s 387us/step - loss:
    0.0206 - accuracy: 0.9934
265 Epoch 133/200
266 50000/50000 [=====] - 19s 384us/step - loss:
    0.0125 - accuracy: 0.9958
267 Epoch 134/200
268 50000/50000 [=====] - 19s 385us/step - loss:
    0.0093 - accuracy: 0.9970
269 Epoch 135/200
270 50000/50000 [=====] - 19s 385us/step - loss:
    0.0142 - accuracy: 0.9951
271 Epoch 136/200
272 50000/50000 [=====] - 19s 385us/step - loss:
    0.0157 - accuracy: 0.9948
273 Epoch 137/200
274 50000/50000 [=====] - 19s 383us/step - loss:
    0.0148 - accuracy: 0.9948
275 Epoch 138/200
276 50000/50000 [=====] - 19s 387us/step - loss:
    0.0131 - accuracy: 0.9957
277 Epoch 139/200
278 50000/50000 [=====] - 20s 393us/step - loss:
    0.0097 - accuracy: 0.9967
279 Epoch 140/200
280 50000/50000 [=====] - 20s 394us/step - loss:
    0.0150 - accuracy: 0.9949
281 Epoch 141/200
282 50000/50000 [=====] - 19s 383us/step - loss:
    0.0172 - accuracy: 0.9941
283 Epoch 142/200
```

```
284 50000/50000 [=====] - 19s 388us/step - loss:
    0.0133 - accuracy: 0.9955
285 Epoch 143/200
286 50000/50000 [=====] - 19s 383us/step - loss:
    0.0102 - accuracy: 0.9968
287 Epoch 144/200
288 50000/50000 [=====] - 19s 380us/step - loss:
    0.0106 - accuracy: 0.9965s - 1
289 Epoch 145/200
290 50000/50000 [=====] - 19s 383us/step - loss:
    0.0110 - accuracy: 0.9964
291 Epoch 146/200
292 50000/50000 [=====] - 19s 383us/step - loss:
    0.0123 - accuracy: 0.9958
293 Epoch 147/200
294 50000/50000 [=====] - 19s 382us/step - loss:
    0.0100 - accuracy: 0.9968
295 Epoch 148/200
296 50000/50000 [=====] - 19s 384us/step - loss:
    0.0082 - accuracy: 0.9972
297 Epoch 149/200
298 50000/50000 [=====] - 19s 380us/step - loss:
    0.0130 - accuracy: 0.9956
299 Epoch 150/200
300 50000/50000 [=====] - 19s 379us/step - loss:
    0.0148 - accuracy: 0.9953
301 Epoch 151/200
302 50000/50000 [=====] - 20s 392us/step - loss:
    0.0093 - accuracy: 0.9969
303 Epoch 152/200
304 50000/50000 [=====] - 20s 409us/step - loss:
    0.0110 - accuracy: 0.9965
305 Epoch 153/200
306 50000/50000 [=====] - 21s 418us/step - loss:
    0.0123 - accuracy: 0.9959
307 Epoch 154/200
308 50000/50000 [=====] - 19s 387us/step - loss:
    0.0097 - accuracy: 0.9965
309 Epoch 155/200
310 50000/50000 [=====] - 19s 390us/step - loss:
    0.0137 - accuracy: 0.9960
311 Epoch 156/200
312 50000/50000 [=====] - 20s 392us/step - loss:
    0.0092 - accuracy: 0.9971
313 Epoch 157/200
314 50000/50000 [=====] - 20s 391us/step - loss:
    0.0111 - accuracy: 0.9963
315 Epoch 158/200
316 50000/50000 [=====] - 19s 384us/step - loss:
    0.0149 - accuracy: 0.9954
317 Epoch 159/200
318 50000/50000 [=====] - 20s 393us/step - loss:
    0.0102 - accuracy: 0.9967
319 Epoch 160/200
320 50000/50000 [=====] - 20s 401us/step - loss:
    0.0067 - accuracy: 0.9978
321 Epoch 161/200
```

```
322 50000/50000 [=====] - 19s 383us/step - loss:
    0.0108 - accuracy: 0.9967
323 Epoch 162/200
324 50000/50000 [=====] - 19s 390us/step - loss:
    0.0078 - accuracy: 0.9975
325 Epoch 163/200
326 50000/50000 [=====] - 20s 400us/step - loss:
    0.0122 - accuracy: 0.9960
327 Epoch 164/200
328 50000/50000 [=====] - 20s 393us/step - loss:
    0.0145 - accuracy: 0.9954s - l
329 Epoch 165/200
330 50000/50000 [=====] - 20s 390us/step - loss:
    0.0114 - accuracy: 0.9963
331 Epoch 166/200
332 50000/50000 [=====] - 19s 384us/step - loss:
    0.0120 - accuracy: 0.9959
333 Epoch 167/200
334 50000/50000 [=====] - 19s 388us/step - loss:
    0.0081 - accuracy: 0.9973s - loss: 0.0080 -
335 Epoch 168/200
336 50000/50000 [=====] - 19s 388us/step - loss:
    0.0117 - accuracy: 0.9961
337 Epoch 169/200
338 50000/50000 [=====] - 19s 384us/step - loss:
    0.0091 - accuracy: 0.9971
339 Epoch 170/200
340 50000/50000 [=====] - 20s 397us/step - loss:
    0.0078 - accuracy: 0.9976s - loss: 0.0075
341 Epoch 171/200
342 50000/50000 [=====] - 19s 389us/step - loss:
    0.0123 - accuracy: 0.9961
343 Epoch 172/200
344 50000/50000 [=====] - 20s 399us/step - loss:
    0.0093 - accuracy: 0.9967
345 Epoch 173/200
346 50000/50000 [=====] - 20s 392us/step - loss:
    0.0323 - accuracy: 0.9904
347 Epoch 174/200
348 50000/50000 [=====] - 22s 449us/step - loss:
    0.0083 - accuracy: 0.9971
349 Epoch 175/200
350 50000/50000 [=====] - 20s 407us/step - loss:
    0.0059 - accuracy: 0.9983
351 Epoch 176/200
352 50000/50000 [=====] - 20s 408us/step - loss:
    0.0100 - accuracy: 0.9968
353 Epoch 177/200
354 50000/50000 [=====] - 20s 401us/step - loss:
    0.0165 - accuracy: 0.9949s - los
355 Epoch 178/200
356 50000/50000 [=====] - 19s 387us/step - loss:
    0.0123 - accuracy: 0.9959
357 Epoch 179/200
358 50000/50000 [=====] - 21s 416us/step - loss:
    0.0056 - accuracy: 0.9982
359 Epoch 180/200
```

```
360 50000/50000 [=====] - 21s 410us/step - loss:
    0.0093 - accuracy: 0.9970
361 Epoch 181/200
362 50000/50000 [=====] - 20s 406us/step - loss:
    0.0050 - accuracy: 0.9980
363 Epoch 182/200
364 50000/50000 [=====] - 21s 421us/step - loss:
    0.0053 - accuracy: 0.9982
365 Epoch 183/200
366 50000/50000 [=====] - 20s 403us/step - loss:
    0.0148 - accuracy: 0.9955
367 Epoch 184/200
368 50000/50000 [=====] - 21s 412us/step - loss:
    0.0134 - accuracy: 0.9959
369 Epoch 185/200
370 50000/50000 [=====] - 21s 416us/step - loss:
    0.0081 - accuracy: 0.9974s - loss: 0.0081 - accura
371 Epoch 186/200
372 50000/50000 [=====] - ETA: 0s - loss: 0.0050 -
    accuracy: 0.9984 ETA: 0s - loss: 0.0051 - accu - 21s 414us/step - loss:
    0.0050 - accuracy: 0.9984
373 Epoch 187/200
374 50000/50000 [=====] - 22s 444us/step - loss:
    0.0084 - accuracy: 0.9974
375 Epoch 188/200
376 50000/50000 [=====] - 23s 457us/step - loss:
    0.0102 - accuracy: 0.9968
377 Epoch 189/200
378 50000/50000 [=====] - 22s 437us/step - loss:
    0.0077 - accuracy: 0.9976
379 Epoch 190/200
380 50000/50000 [=====] - 21s 420us/step - loss:
    0.0083 - accuracy: 0.9972
381 Epoch 191/200
382 50000/50000 [=====] - 21s 410us/step - loss:
    0.0118 - accuracy: 0.9959s -
383 Epoch 192/200
384 50000/50000 [=====] - 20s 409us/step - loss:
    0.0071 - accuracy: 0.9977
385 Epoch 193/200
386 50000/50000 [=====] - 20s 394us/step - loss:
    0.0061 - accuracy: 0.9981
387 Epoch 194/200
388 50000/50000 [=====] - 20s 410us/step - loss:
    0.0063 - accuracy: 0.9980
389 Epoch 195/200
390 50000/50000 [=====] - 20s 396us/step - loss:
    0.0090 - accuracy: 0.9969
391 Epoch 196/200
392 50000/50000 [=====] - 20s 399us/step - loss:
    0.0080 - accuracy: 0.9973
393 Epoch 197/200
394 50000/50000 [=====] - 20s 405us/step - loss:
    0.0115 - accuracy: 0.9963s - 1
395 Epoch 198/200
396 50000/50000 [=====] - 21s 421us/step - loss:
    0.0095 - accuracy: 0.9969
397 Epoch 199/200
```

```
398 50000/50000 [=====] - 20s 400us/step - loss:
    0.0063 - accuracy: 0.9977
399 Epoch 200/200
400 50000/50000 [=====] - 20s 400us/step - loss:
    0.0100 - accuracy: 0.9968
401 10000/10000 [=====] - 5s 523us/step
402 Loss = 1.8030616061210631
403 Test Accuracy = 0.7542999982833862
```