REPORT

Assignment 3:

Building your own convolutional neural networks

MR.CHALERMKIAT CHANAHCHAN

ID: 62070701602

King Mongkut's University of Technology Thonburi

Faculty of Engineering, Department of Computer Engineering

CPE 663 Special Topic: Deep Learning, 1/2019

Assignment 3: Building your own convolutional neural networks

Due: 7 November 2019. Please submit your report in PDF to LEB2

Introduction

In this assignment, we will design and implement the convolutional neural network to classify CIFAR10. An initial guide can be found in the Keras documentation, but **students are encouraged to come up with their own design or** modify the success case.

Tasks

1. Load and explore CIFAR10 data.
2. Design the convolutional neural networks.
3. Justify and explain your design.
4. Train the model.
5. Evaluate the results.

Tasks 1: Load and explore CIFAR10 data.

Load CIFAR10 data

Code:

```
# The data, split between train and test sets:
(x_train, y_train), (x_test, y_test) = cifar10.load_data()
print('x_train shape:', x_train.shape)
print(x_train.shape[0], 'train samples')
print(x_test.shape[0], 'test samples')
```

Output:

x_train shape: (50000, 32, 32, 3)

50000 train samples

10000 test samples

Example of Training data each:

```
[[[[ 59  62  63]
   [ 43  46  45]
   [ 50  48  43]
   ...
   [158 132 108]
   [152 125 102]
   [148 124 103]]

  [[ 16  20  20]
   [  0   0   0]
   [ 18   8   0]
   ...
```

Example figure of traing data:

```
from matplotlib import pyplot
sample_id = 10000
pyplot.imshow(X_train[sample_id])
pyplot.show()
```

Figure ID = 1000

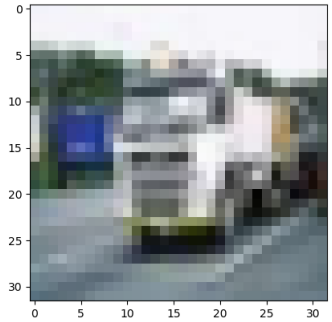


Figure ID = 3000

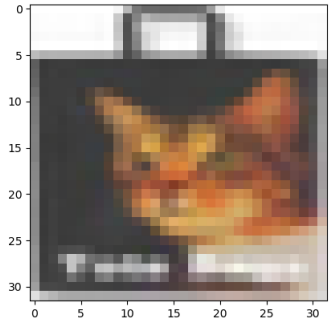
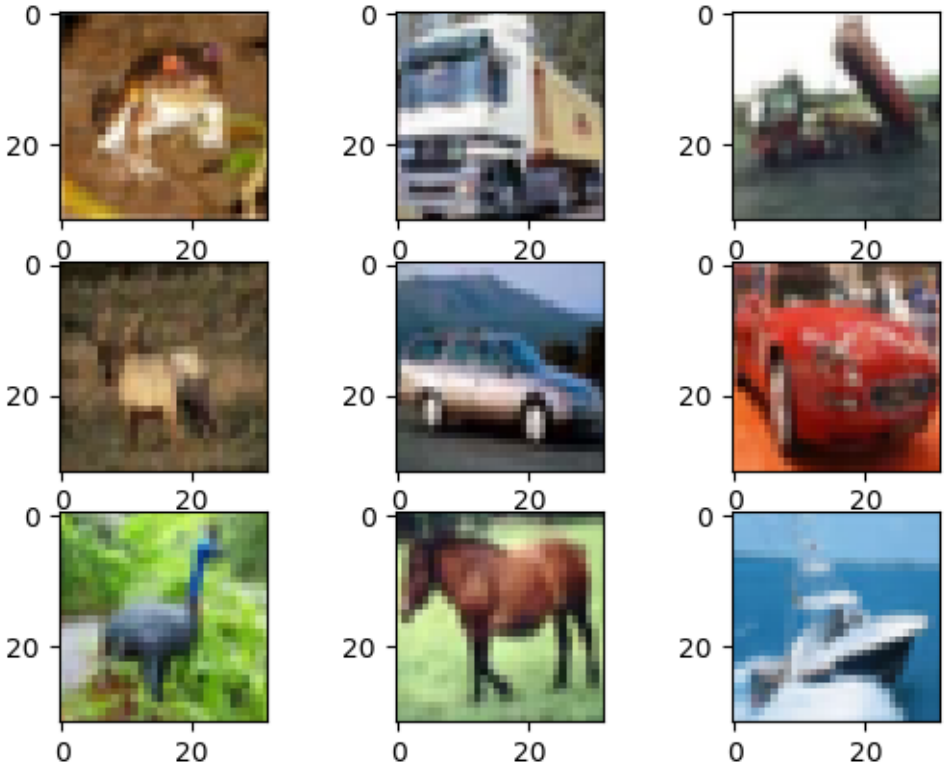


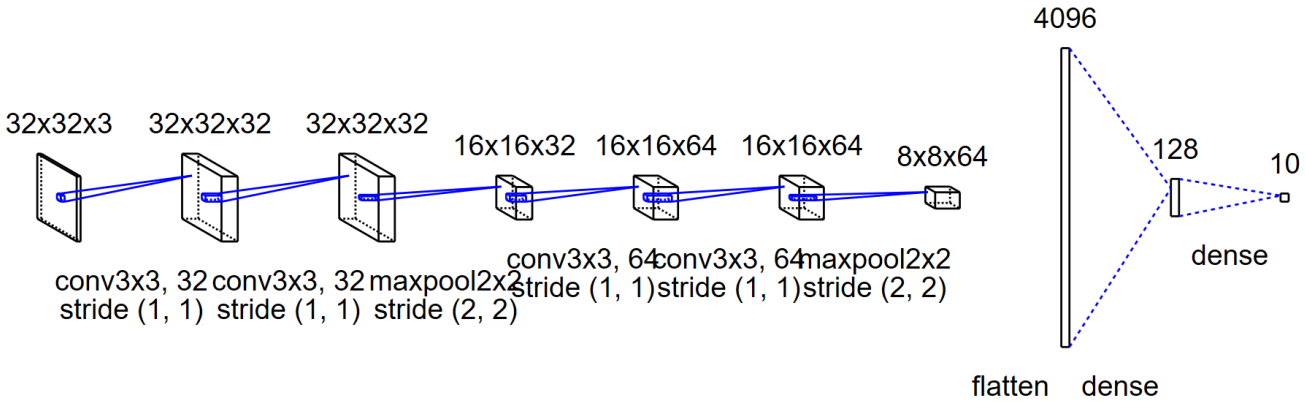
Figure ID = 10000

Example Figure ID 0 to 8 in 3x3 grid plot:



Tasks 2: Design the convolutional neural networks.

My design Model:



Drawn by Mr.Chalermkiat Chanachan using convet-drawer (https://github.com/yu4u/convnet-drawer)

Tasks 3: Justify and explain your design.

I think if CNN is not reducing matrix in the model what it happens then I try to design model with the same matrix in Layers (1, 2, 3 and 4, 5).

My model has 2 parts. First part is 7 convolutional layers and second part is 3 connected layers. At convolutional layers in the first- and second-layer use activation function with ReLU function. the third Layer use is pooling layer with max-pooling 2x2 dimension. the fourth- and fifth-layer use activation function with tanh function. the sixth layer is pooling layer with max-pooling 2x2 dimension. After flattening into one dimensional (vector) use sigmoid function and the last layer use SoftMax function. My model optimizes ADAM and calculate loss function with cross-entropy or log loss.

Tasks 4: Train the model.

Code:

```
model = Sequential()

model.add(Conv2D(32, (3, 3), activation='relu', padding='same', input_shape=(32, 32, 3)))
model.add(Conv2D(32, (3, 3), activation='relu', padding='same'))
model.add(MaxPooling2D(pool_size=((2, 2)))

model.add(Conv2D(64, (3, 3), activation='tanh', padding='same'))
model.add(Conv2D(64, (3, 3), activation='tanh', padding='same'))
model.add(MaxPooling2D(pool_size=(2, 2)))

model.add(Flatten())
model.add(Dense(128, activation='sigmoid', kernel_initializer='he_uniform'))
model.add(Dense(10, activation='softmax'))
opt = keras.optimizers.Adam(learning_rate=0.001, beta_1=0.9, beta_2=0.999, amsgrad=False)

# Let's train the model using RMSprop
model.compile(loss='categorical_crossentropy',
              optimizer=opt,
              metrics=['accuracy'])
```

Output:

No Color = calculating times with full performance (CPU compute) = ~ 180 s

Yellow Color = Calculating times with better performance = ~400 s

Red Color = Calculating times when I am sleeping my computer = > 500

```
Using real-time data augmentation.
Epoch 1/100
1563/1563 [==============================] - 197s 126ms/step - loss: 1.4489 - accuracy: 0.4747 - val_loss: 1.2016 - val_accuracy
Epoch 2/100
1563/1563 [==============================] - 196s 125ms/step - loss: 1.0718 - accuracy: 0.6207 - val_loss: 0.9462 - val_accuracy
Epoch 3/100
1563/1563 [==============================] - 194s 124ms/step - loss: 0.9474 - accuracy: 0.6653 - val_loss: 0.8820 - val_accuracy
Epoch 4/100
1563/1563 [==============================] - 187s 120ms/step - loss: 0.8703 - accuracy: 0.6950 - val_loss: 0.7765 - val_accuracy
Epoch 5/100
1563/1563 [==============================] - 183s 117ms/step - loss: 0.8175 - accuracy: 0.7139 - val_loss: 0.8358 - val_accuracy
Epoch 6/100
1563/1563 [==============================] - 252s 161ms/step - loss: 0.7906 - accuracy: 0.7241 - val_loss: 0.7268 - val_accuracy
Epoch 7/100
1563/1563 [==============================] - 403s 258ms/step - loss: 0.7475 - accuracy: 0.7364 - val_loss: 0.7746 - val_accuracy
Epoch 8/100
1563/1563 [==============================] - 403s 258ms/step - loss: 0.7236 - accuracy: 0.7470 - val_loss: 0.7360 - val_accuracy
```

```
Epoch 9/100
1563/1563 [==============================] - 406s 260ms/step - loss: 0.7042 - accuracy: 0.7541 - val_loss: 0.7263 - val_accuracy
Epoch 10/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.6875 - accuracy: 0.7605 - val_loss: 0.7206 - val_accuracy
Epoch 11/100
1563/1563 [==============================] - 405s 259ms/step - loss: 0.6792 - accuracy: 0.7626 - val_loss: 0.6916 - val_accuracy
Epoch 12/100
1563/1563 [==============================] - 404s 259ms/step - loss: 0.6612 - accuracy: 0.7685 - val_loss: 0.6788 - val_accuracy
Epoch 13/100
1563/1563 [==============================] - 403s 258ms/step - loss: 0.6464 - accuracy: 0.7723 - val_loss: 0.6684 - val_accuracy
Epoch 14/100
1563/1563 [==============================] - 404s 258ms/step - loss: 0.6422 - accuracy: 0.7745 - val_loss: 0.7059 - val_accuracy
Epoch 15/100
1563/1563 [==============================] - 404s 259ms/step - loss: 0.6315 - accuracy: 0.7795 - val_loss: 0.6757 - val_accuracy
Epoch 16/100
1563/1563 [==============================] - 404s 259ms/step - loss: 0.6219 - accuracy: 0.7842 - val_loss: 0.6772 - val_accuracy
Epoch 17/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.6114 - accuracy: 0.7874 - val_loss: 0.6287 - val_accuracy
Epoch 18/100
1563/1563 [==============================] - 406s 260ms/step - loss: 0.6127 - accuracy: 0.7869 - val_loss: 0.6659 - val_accuracy
Epoch 19/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.5997 - accuracy: 0.7905 - val_loss: 0.6503 - val_accuracy
Epoch 20/100
1563/1563 [==============================] - 403s 258ms/step - loss: 0.5913 - accuracy: 0.7917 - val_loss: 0.6479 - val_accuracy
Epoch 21/100
1563/1563 [==============================] - 405s 259ms/step - loss: 0.5910 - accuracy: 0.7934 - val_loss: 0.6140 - val_accuracy
Epoch 22/100
1563/1563 [==============================] - 406s 260ms/step - loss: 0.5831 - accuracy: 0.7956 - val_loss: 0.6340 - val_accuracy
Epoch 23/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.5821 - accuracy: 0.7959 - val_loss: 0.6825 - val_accuracy
Epoch 24/100
1563/1563 [==============================] - 404s 259ms/step - loss: 0.5741 - accuracy: 0.8004 - val_loss: 0.6572 - val_accuracy
Epoch 25/100
1563/1563 [==============================] - 411s 263ms/step - loss: 0.5743 - accuracy: 0.7968 - val_loss: 0.6550 - val_accuracy
Epoch 26/100
1563/1563 [==============================] - 410s 262ms/step - loss: 0.5723 - accuracy: 0.8004 - val_loss: 0.6567 - val_accuracy
Epoch 27/100
1563/1563 [==============================] - 404s 259ms/step - loss: 0.5623 - accuracy: 0.8033 - val_loss: 0.6638 - val_accuracy
Epoch 28/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.5605 - accuracy: 0.8027 - val_loss: 0.6266 - val_accuracy
Epoch 29/100
1563/1563 [==============================] - 405s 259ms/step - loss: 0.5510 - accuracy: 0.8068 - val_loss: 0.6606 - val_accuracy
Epoch 30/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.5596 - accuracy: 0.8022 - val_loss: 0.6460 - val_accuracy
Epoch 31/100
1563/1563 [==============================] - 403s 258ms/step - loss: 0.5559 - accuracy: 0.8042 - val_loss: 0.6567 - val_accuracy
Epoch 32/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.5509 - accuracy: 0.8073 - val_loss: 0.6221 - val_accuracy
Epoch 33/100
1563/1563 [==============================] - 404s 259ms/step - loss: 0.5505 - accuracy: 0.8071 - val_loss: 0.6248 - val_accuracy
Epoch 34/100
1563/1563 [==============================] - 401s 257ms/step - loss: 0.5375 - accuracy: 0.8106 - val_loss: 0.6391 - val_accuracy
Epoch 35/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.5377 - accuracy: 0.8115 - val_loss: 0.6416 - val_accuracy
```

```
Epoch 36/100
1563/1563 [==============================] - 404s 259ms/step - loss: 0.5404 - accuracy: 0.8127 - val_loss: 0.6468 - val_accuracy
Epoch 37/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.5390 - accuracy: 0.8121 - val_loss: 0.6314 - val_accuracy
Epoch 38/100
1563/1563 [==============================] - 404s 258ms/step - loss: 0.5377 - accuracy: 0.8101 - val_loss: 0.6460 - val_accuracy
Epoch 39/100
1563/1563 [==============================] - 405s 259ms/step - loss: 0.5331 - accuracy: 0.8134 - val_loss: 0.6623 - val_accuracy
Epoch 40/100
1563/1563 [==============================] - 403s 258ms/step - loss: 0.5331 - accuracy: 0.8135 - val_loss: 0.6279 - val_accuracy
Epoch 41/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.5272 - accuracy: 0.8163 - val_loss: 0.6553 - val_accuracy
Epoch 42/100
1563/1563 [==============================] - 405s 259ms/step - loss: 0.5307 - accuracy: 0.8149 - val_loss: 0.6570 - val_accuracy
Epoch 43/100
1563/1563 [==============================] - 405s 259ms/step - loss: 0.5248 - accuracy: 0.8153 - val_loss: 0.6487 - val_accuracy
Epoch 44/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.5265 - accuracy: 0.8147 - val_loss: 0.6328 - val_accuracy
Epoch 45/100
1563/1563 [==============================] - 404s 259ms/step - loss: 0.5206 - accuracy: 0.8173 - val_loss: 0.6524 - val_accuracy
Epoch 46/100
1563/1563 [==============================] - 403s 258ms/step - loss: 0.5170 - accuracy: 0.8209 - val_loss: 0.6661 - val_accuracy
Epoch 47/100
1563/1563 [==============================] - 406s 260ms/step - loss: 0.5187 - accuracy: 0.8158 - val_loss: 0.6338 - val_accuracy
Epoch 48/100
1563/1563 [==============================] - 404s 259ms/step - loss: 0.5284 - accuracy: 0.8134 - val_loss: 0.6234 - val_accuracy
Epoch 49/100
1563/1563 [==============================] - 404s 259ms/step - loss: 0.5195 - accuracy: 0.8186 - val_loss: 0.6892 - val_accuracy
Epoch 50/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.5156 - accuracy: 0.8185 - val_loss: 0.6136 - val_accuracy
Epoch 51/100
1563/1563 [==============================] - 406s 259ms/step - loss: 0.5101 - accuracy: 0.8215 - val_loss: 0.6170 - val_accuracy
Epoch 52/100
1563/1563 [==============================] - 403s 258ms/step - loss: 0.5091 - accuracy: 0.8204 - val_loss: 0.6165 - val_accuracy
Epoch 53/100
1563/1563 [==============================] - 403s 258ms/step - loss: 0.5135 - accuracy: 0.8198 - val_loss: 0.6020 - val_accuracy
Epoch 54/100
1563/1563 [==============================] - 404s 258ms/step - loss: 0.5099 - accuracy: 0.8217 - val_loss: 0.6276 - val_accuracy
Epoch 55/100
1563/1563 [==============================] - 401s 257ms/step - loss: 0.5057 - accuracy: 0.8218 - val_loss: 0.6090 - val_accuracy
Epoch 56/100
1563/1563 [==============================] - 404s 259ms/step - loss: 0.5043 - accuracy: 0.8240 - val_loss: 0.6234 - val_accuracy
Epoch 57/100
1563/1563 [==============================] - 406s 259ms/step - loss: 0.5055 - accuracy: 0.8241 - val_loss: 0.6287 - val_accuracy
Epoch 58/100
1563/1563 [==============================] - 406s 260ms/step - loss: 0.5109 - accuracy: 0.8213 - val_loss: 0.6554 - val_accuracy
Epoch 59/100
1563/1563 [==============================] - 404s 258ms/step - loss: 0.5033 - accuracy: 0.8240 - val_loss: 0.6129 - val_accuracy
Epoch 60/100
1563/1563 [==============================] - 405s 259ms/step - loss: 0.5059 - accuracy: 0.8226 - val_loss: 0.6299 - val_accuracy
Epoch 61/100
1563/1563 [==============================] - 405s 259ms/step - loss: 0.5066 - accuracy: 0.8222 - val_loss: 0.6217 - val_accuracy
Epoch 62/100
1563/1563 [==============================] - 403s 258ms/step - loss: 0.5031 - accuracy: 0.8238 - val_loss: 0.6430 - val_accuracy
```

Epoch 63/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.5042 - accuracy: 0.8224 - val_loss: 0.6317 - val_accuracy
Epoch 64/100
1563/1563 [==============================] - 402s 257ms/step - loss: 0.5086 - accuracy: 0.8212 - val_loss: 0.6294 - val_accuracy
Epoch 65/100
1563/1563 [==============================] - 403s 258ms/step - loss: 0.4994 - accuracy: 0.8255 - val_loss: 0.6351 - val_accuracy
Epoch 66/100
1563/1563 [==============================] - 302s 193ms/step - loss: 0.5050 - accuracy: 0.8211 - val_loss: 0.6051 - val_accuracy
Epoch 67/100
1563/1563 [==============================] - 181s 116ms/step - loss: 0.4986 - accuracy: 0.8245 - val_loss: 0.6308 - val_accuracy
Epoch 68/100
1563/1563 [==============================] - 183s 117ms/step - loss: 0.5000 - accuracy: 0.8257 - val_loss: 0.6475 - val_accuracy
Epoch 69/100
1563/1563 [==============================] - 182s 116ms/step - loss: 0.4959 - accuracy: 0.8256 - val_loss: 0.6816 - val_accuracy
Epoch 70/100
1563/1563 [==============================] - 185s 118ms/step - loss: 0.4971 - accuracy: 0.8276 - val_loss: 0.6702 - val_accuracy
Epoch 71/100
1563/1563 [==============================] - 183s 117ms/step - loss: 0.4913 - accuracy: 0.8269 - val_loss: 0.6446 - val_accuracy
Epoch 72/100
1563/1563 [==============================] - 182s 117ms/step - loss: 0.4920 - accuracy: 0.8274 - val_loss: 0.6236 - val_accuracy
Epoch 73/100
1563/1563 [==============================] - 184s 117ms/step - loss: 0.4892 - accuracy: 0.8306 - val_loss: 0.6561 - val_accuracy
Epoch 74/100
1563/1563 [==============================] - 181s 116ms/step - loss: 0.4998 - accuracy: 0.8255 - val_loss: 0.6279 - val_accuracy
Epoch 75/100
1563/1563 [==============================] - 181s 116ms/step - loss: 0.4895 - accuracy: 0.8287 - val_loss: 0.6106 - val_accuracy
Epoch 76/100
1563/1563 [==============================] - 181s 116ms/step - loss: 0.4898 - accuracy: 0.8288 - val_loss: 0.6356 - val_accuracy
Epoch 77/100
1563/1563 [==============================] - 181s 116ms/step - loss: 0.4818 - accuracy: 0.8290 - val_loss: 0.6200 - val_accuracy
Epoch 78/100
1563/1563 [==============================] - 185s 118ms/step - loss: 0.4925 - accuracy: 0.8265 - val_loss: 0.6159 - val_accuracy
Epoch 79/100
1563/1563 [==============================] - 196s 126ms/step - loss: 0.4926 - accuracy: 0.8279 - val_loss: 0.6166 - val_accuracy
Epoch 80/100
1563/1563 [==============================] - 193s 123ms/step - loss: 0.4970 - accuracy: 0.8260 - val_loss: 0.6562 - val_accuracy
Epoch 81/100
1563/1563 [==============================] - 352s 225ms/step - loss: 0.4964 - accuracy: 0.8247 - val_loss: 0.6082 - val_accuracy
Epoch 82/100
1563/1563 [==============================] - 391s 250ms/step - loss: 0.4897 - accuracy: 0.8286 - val_loss: 0.6374 - val_accuracy
Epoch 83/100
1563/1563 [==============================] - 388s 248ms/step - loss: 0.4902 - accuracy: 0.8278 - val_loss: 0.6541 - val_accuracy
Epoch 84/100
1563/1563 [==============================] - 383s 245ms/step - loss: 0.4856 - accuracy: 0.8304 - val_loss: 0.6904 - val_accuracy
Epoch 85/100
1563/1563 [==============================] - 380s 243ms/step - loss: 0.4849 - accuracy: 0.8297 - val_loss: 0.6553 - val_accuracy
Epoch 86/100
1563/1563 [==============================] - 3666s 2s/step - loss: 0.4913 - accuracy: 0.8285 - val_loss: 0.6322 - val_accuracy:
Epoch 87/100
1563/1563 [==============================] - 223s 143ms/step - loss: 0.4899 - accuracy: 0.8276 - val_loss: 0.6401 - val_accuracy
Epoch 88/100
1563/1563 [==============================] - 229s 147ms/step - loss: 0.4931 - accuracy: 0.8275 - val_loss: 0.6260 - val_accuracy
Epoch 89/100
1563/1563 [==============================] - 193s 123ms/step - loss: 0.4916 - accuracy: 0.8285 - val_loss: 0.6360 - val_accuracy

```
Epoch 90/100
1563/1563 [==============================] - 193s 123ms/step - loss: 0.4857 - accuracy: 0.8278 - val_loss: 0.6294 - val_accuracy
Epoch 91/100
1563/1563 [==============================] - 196s 125ms/step - loss: 0.4906 - accuracy: 0.8277 - val_loss: 0.6158 - val_accuracyuracy: 0.8277 - val_loss:
0.6158 - val_accuracy: 0.7954
Epoch 92/100                                                  uracy: 0.8295 - val_loss: 0.6274 - val_accuracy
1563/1563 [==============================] - 200s 128ms/step - loss: 0.4814 - accuracy: 0.8295 - val_loss: 0.6274 - val_accuracy: 0.7942
uracy: 0.8275 - val_loss: 0.6125 - val_accuracy
Epoch 93/100
1563/1563 [==============================] - 198s 127ms/step - loss: 0.4908 - accuracy: 0.8286 - val_loss: 0.6132 - val_accuracyuracy: 0.8275 - val_loss:
0.6125 - val_accuracy: 0.7939
Epoch 94/100                                                  uracy: 0.8287 - val_loss: 0.6318 - val_accuracy
1563/1563 [==============================] - 192s 123ms/step - loss: 0.4873 - accuracy: 0.8286 - val_loss: 0.6132 - val_accuracy: 0.7980
uracy: 0.8280 - val_loss: 0.6299 - val_accuracy
Epoch 95/100
1563/1563 [==============================] - 183s 117ms/step - loss: 0.4882 - accuracy: 0.8287 - val_loss: 0.6318 - val_accuracyuracy: 0.8287 - val_loss:
0.6318 - val_accuracy: 0.7918
Epoch 96/100                                                  uracy: 0.8280 - val_loss: 0.6299 - val_accuracy
1563/1563 [==============================] - 182s 116ms/step - loss: 0.4891 - accuracy: 0.8280 - val_loss: 0.6299 - val_accuracy: 0.7945
uracy: 0.8297 - val_loss: 0.6467 - val_accuracy
Epoch 97/100
1563/1563 [==============================] - 185s 118ms/step - loss: 0.4847 - accuracy: 0.8297 - val_loss: 0.6467 - val_accuracy
Epoch 98/100
1563/1563 [==============================] - 184s 118ms/step - loss: 0.4911 - accuracy: 0.8273 - val_loss: 0.6538 - val_accuracy
Epoch 99/100
1563/1563 [==============================] - 183s 117ms/step - loss: 0.4901 - accuracy: 0.8290 - val_loss: 0.6140 - val_accuracy
Epoch 100/100
1563/1563 [==============================] - 181s 116ms/step - loss: 0.4949 - accuracy: 0.8253 - val_loss: 0.6279 - val_accuracy
Saved trained model at D:\Master_Degree\DeepLearning\Documents\A3\saved_models\keras_cifar10_trained_model-final.h5
10000/10000 [==============================] - 7s 689us/step
```

Tasks 5: Evaluate the results.

Code:

```
# Score trained model.
scores = model.evaluate(x_test, y_test, verbose=1)
print('Test loss:', scores[0])
print('Test accuracy:', scores[1])
```

Testing Results:

Test loss: 0.6278955207347869

Test accuracy: 0.7918999791145325

Comparing the results between Keras document example and Keras document example.

- 100 Epochs

	Keras Document Example	My Design Model
Test Loss	0.7624230746269226	0.6278955207347869
Test Accuracy	0.7490000128746033	0.7918999791145325

Capture output figure when finished:

```
Epoch 98/100
1563/1563 [==============================] - 226s 145ms/step - loss: 0.8037 - accuracy: 0.7354 - val_loss: 0.7239 - val_accuracy: 0.7567
Epoch 99/100
1563/1563 [==============================] - 211s 135ms/step - loss: 0.8020 - accuracy: 0.7348 - val_loss: 0.6842 - val_accuracy: 0.7777
Epoch 100/100
1563/1563 [==============================] - 209s 134ms/step - loss: 0.8072 - accuracy: 0.7340 - val_loss: 0.7624 - val_accuracy: 0.7490
Saved trained model at D:\Master_Degree\DeepLearning\Documents\A3\saved_models\keras_cifar10_trained_model.h5
10000/10000 [==============================] - 7s 688us/step
Test loss: 0.7624230746269226
Test accuracy: 0.7490000128746033
```