118430Q5_2

July 7, 2020

IA353 - Redes Neurais

EFC3 - Questão 5

DAE - Denoising Autoencoder (training and visualization)

dataset: CIFAR-10

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5.1. Imports

[ ]:
```
import tensorflow as tf
import os
from multiprocessing import cpu_count

import warnings
warnings.filterwarnings('ignore')

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

from sklearn import metrics
from sklearn.neighbors import NearestNeighbors

from keras.models import Sequential, Model
from keras.layers import Dense, Dropout, Convolution2D, MaxPooling2D, Flatten, Input,␣
↪Conv2D, UpSampling2D, Reshape, Deconvolution2D, Conv2DTranspose, BatchNormalization,␣
↪LeakyReLU, add
from keras.optimizers import adam
from keras.utils.np_utils import to_categorical
```

```
Using TensorFlow backend.
```

[ ]:
```
# version
tf.__version__
```

[ ]:
```
'2.2.0'
```

[ ]:
```
#-------------------------------------------------
# additional config
#------------------
```

```
# random seed generator
os.environ['PYTHONHASHSEED']=str(42)
np.random.seed(42)
tf.random.set_seed(42)
os.environ['TF_DETERMINISTIC_OPS'] = '1'
```

[ ]:
```
# choose between CPU and GPU
device = tf.device('/cpu:0')
if tf.config.list_physical_devices('GPU'):
    device = tf.device('/device:GPU:0')
#    device_model = torch.cuda.get_device_name(0)
#    device_memory = torch.cuda.get_device_properties(device).total_memory / 1e9
    device_number = len(tf.config.experimental.list_physical_devices('GPU'))
    #----------------------------
    #from tensorflow.python.client import device_lib
    #print(device_lib.list_local_devices())
    #----------------------------
    print('Device: gpu')
    #print('GPU model:', device_model)
    #print('GPU memory: {0:.2f} GB'.format(device_memory))
    print("GPUs available: ", device_number)
    print('#-------------------')
print('CPU cores:', cpu_count())
```

```
Device: gpu
GPUs available:  1
#-------------------
CPU cores: 2
```

5.2. Reading the data

[ ]:
```
cifar10 = tf.keras.datasets.cifar10
(x_train, y_train),(x_test, y_test) = cifar10.load_data()
```

[ ]:
```
x_train, x_test = x_train / 255.0, x_test / 255.0
```

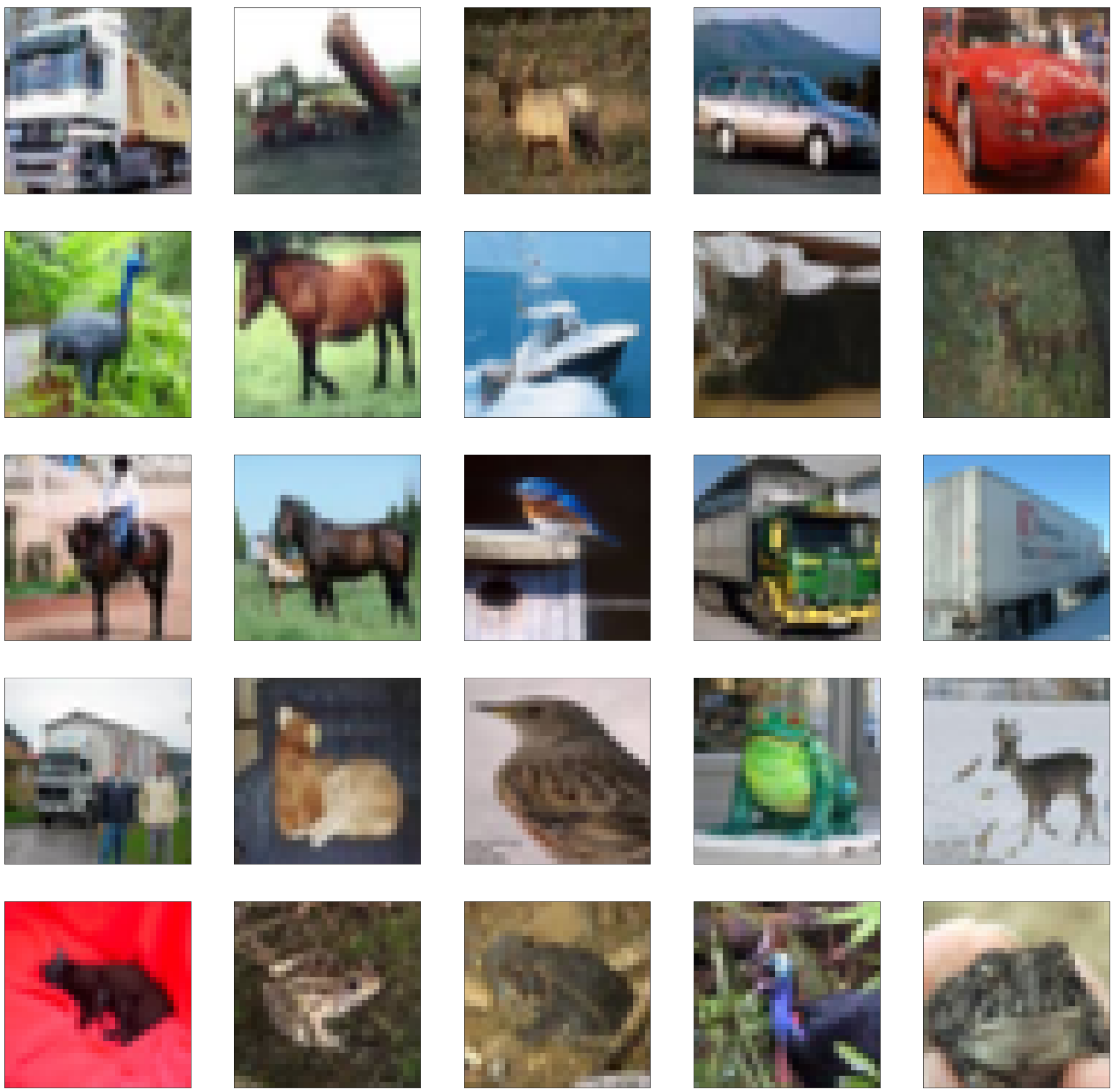
[ ]:
```
x_images = x_train.reshape(x_train.shape[0], 32, 32, 3)
```

[ ]:
```
# Definition of a function to visualize some images
def show(img):
    plt.imshow(img, cmap = None, interpolation = "none")
```

[ ]:
```
# Visualization of 25 x 25 original images
fig = plt.figure(figsize=(32,32))
ind = 1
for i in range(1, 26, 1):
    for j in range(1, 26, 1):
        fig.add_subplot(25,25,ind)
        show(x_images[ind])
        plt.xticks([])
        plt.yticks([])
        ind+=1
```

Original images

```
[ ]: # Visualization of 5 x 5 original images
fig = plt.figure(figsize=(32,32))
ind = 1
for i in range(1, 6, 1):
    for j in range(1, 6, 1):
        fig.add_subplot(5,5,ind)
        show(x_images[ind])
        plt.xticks([])
        plt.yticks([])
        ind+=1
```



Noisy images

[ ]:
```python
# Adding noise (mean = 0; std = 0.3)
noise = 0.3
x_train_noise = x_train + noise * np.random.normal(0, 0.3, size=x_train.shape)
x_test_noise = x_test + noise * np.random.normal(0, 0.3, size=x_test.shape)
```

[ ]:
```python
# Visualization of 5 x 5 noisy images
fig = plt.figure(figsize=(32,32))
ind = 1
for i in range(1, 6, 1):
    for j in range(1, 6, 1):
        fig.add_subplot(5,5,ind)
        show(x_train_noise[ind])
        plt.xticks([])
        plt.yticks([])
        ind+=1
```

```
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floats or [0..255] for integers).
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```

5.3 Proposal for the autoencoder architecture

Architecture and training history:

- Step 1: Training autoencoder with images without noise, just aiming image reconstruction.
- Step 2: Added BatchNorm layers.
- Step 3: Added Dropout layers.
- Step 4: Added skip connection (shortcut).

Reconstruction OK!

- Step 5: Added noise to input images and trained again.
- Step 6: Parameters adjusted.
- Step 7: Final training (architecture below).

[ ]:

```
input_img = Input(shape=(32,32,3,))             # (50000,32,32,3)
#============================================================
encoded = Conv2D(32, (3, 3), activation='relu', strides=2, padding='same')(input_img)            # (50000,32,32,32)
encoded = BatchNormalization()(encoded)
encoded = Dropout(0.5)(encoded)
#------------------------------
skip = Conv2D(64, (3, 3), activation=None, strides=2, padding='same')(encoded)             # (50000,16,16,32)
encoded = LeakyReLU()(skip)
encoded = BatchNormalization()(encoded)
encoded = Dropout(0.5)(encoded)
#------------------------------
encoded = Conv2D(128, (3, 3), activation='relu', strides=2, padding='same')(encoded)            # (50000,8,8,64)
encoded = BatchNormalization()(encoded)
#------------------------------
encoded = Flatten()(encoded)                                # (50000,1024)
#============================================================
encoded = Dense(50, activation=None)(encoded)               # (50000,10) --> bottleneck
#============================================================
decoded = Dense(2048, activation='tanh')(encoded)           # (50000,1152)
decoded = Reshape((4, 4, 128))(decoded)             # (50000,4,4,128)
#------------------------------
decoded = Conv2DTranspose(64, (3,3), strides=2, activation='relu', padding='same')(decoded)      # (50000,8,8,64)
decoded = add([decoded, skip])
decoded = LeakyReLU()(decoded)
decoded = BatchNormalization()(decoded)
#------------------------------
decoded = Conv2DTranspose(32, (3,3), strides=2, activation=None, padding='same')(decoded)        # (50000,16,16,32)
decoded = BatchNormalization()(decoded)
decoded = Dropout(0.5)(decoded)
#------------------------------
decoded = Conv2DTranspose(3, (3,3), strides=2, activation='sigmoid', padding='same')(decoded)    # (50000,32,32,3)
#============================================================
autoencoder = Model(input=input_img, output=decoded)
```

[ ]:

```
autoencoder.summary()
```

```
Model: "model_1"
__________________________________________________________________________________
__________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================
==================
input_1 (InputLayer)            (None, 32, 32, 3)    0
__________________________________________________________________________________
__________________
conv2d_1 (Conv2D)               (None, 16, 16, 32)   896         input_1[0][0]
__________________________________________________________________________________
__________________
batch_normalization_1 (BatchNor (None, 16, 16, 32)   128         conv2d_1[0][0]
__________________________________________________________________________________
__________________
dropout_1 (Dropout)             (None, 16, 16, 32)   0
batch_normalization_1[0][0]
__________________________________________________________________________________
__________________
conv2d_2 (Conv2D)               (None, 8, 8, 64)     18496       dropout_1[0][0]
__________________________________________________________________________________
__________________
leaky_re_lu_1 (LeakyReLU)       (None, 8, 8, 64)     0           conv2d_2[0][0]
__________________________________________________________________________________
__________________
batch_normalization_2 (BatchNor (None, 8, 8, 64)     256
leaky_re_lu_1[0][0]
__________________________________________________________________________________
__________________
dropout_2 (Dropout)             (None, 8, 8, 64)     0
batch_normalization_2[0][0]
__________________________________________________________________________________
__________________
conv2d_3 (Conv2D)               (None, 4, 4, 128)    73856       dropout_2[0][0]
__________________________________________________________________________________
__________________
batch_normalization_3 (BatchNor (None, 4, 4, 128)    512         conv2d_3[0][0]
__________________________________________________________________________________
__________________
flatten_1 (Flatten)             (None, 2048)         0
batch_normalization_3[0][0]
__________________________________________________________________________________
__________________
dense_1 (Dense)                 (None, 50)           102450      flatten_1[0][0]
__________________________________________________________________________________
__________________
dense_2 (Dense)                 (None, 2048)         104448      dense_1[0][0]
__________________________________________________________________________________
__________________
reshape_1 (Reshape)             (None, 4, 4, 128)    0           dense_2[0][0]
__________________________________________________________________________________
__________________
conv2d_transpose_1 (Conv2DTrans (None, 8, 8, 64)     73792       reshape_1[0][0]
__________________________________________________________________________________
```

```
__________________
add_1 (Add)                      (None, 8, 8, 64)     0
conv2d_transpose_1[0][0]
                                                                  conv2d_2[0][0]
________________________________________________________________________________
__________________
leaky_re_lu_2 (LeakyReLU)        (None, 8, 8, 64)     0           add_1[0][0]
________________________________________________________________________________
__________________
batch_normalization_4 (BatchNor (None, 8, 8, 64)     256
leaky_re_lu_2[0][0]
________________________________________________________________________________
__________________
conv2d_transpose_2 (Conv2DTrans (None, 16, 16, 32)   18464
batch_normalization_4[0][0]
________________________________________________________________________________
__________________
batch_normalization_5 (BatchNor (None, 16, 16, 32)   128
conv2d_transpose_2[0][0]
________________________________________________________________________________
__________________
dropout_3 (Dropout)              (None, 16, 16, 32)   0
batch_normalization_5[0][0]
________________________________________________________________________________
__________________
conv2d_transpose_3 (Conv2DTrans (None, 32, 32, 3)    867         dropout_3[0][0]
================================================================================
==================
Total params: 394,549
Trainable params: 393,909
Non-trainable params: 640
________________________________________________________________________________
__________________
```

Training

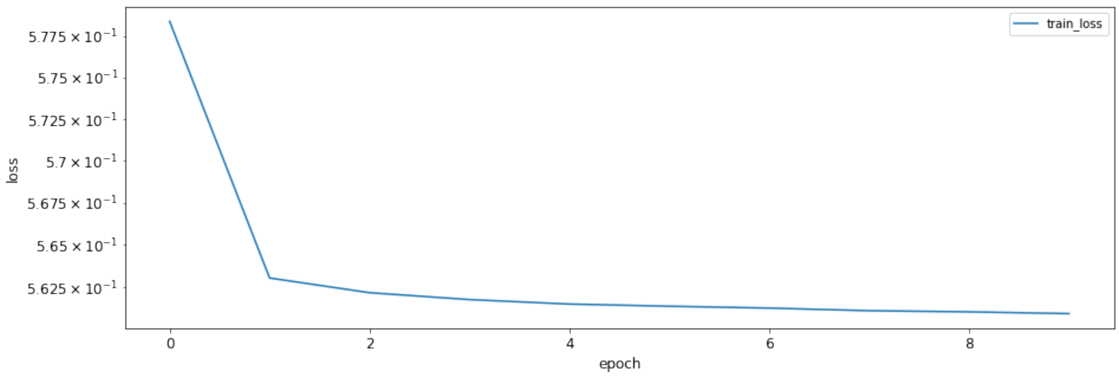
[ ]:

```
with device:
    autoencoder.compile(optimizer='adam', loss = "binary_crossentropy")
    history = autoencoder.fit(
        x_train_noise,
        x_train,
        batch_size = 128,
        nb_epoch = 10,
        verbose = 1,
    )
```

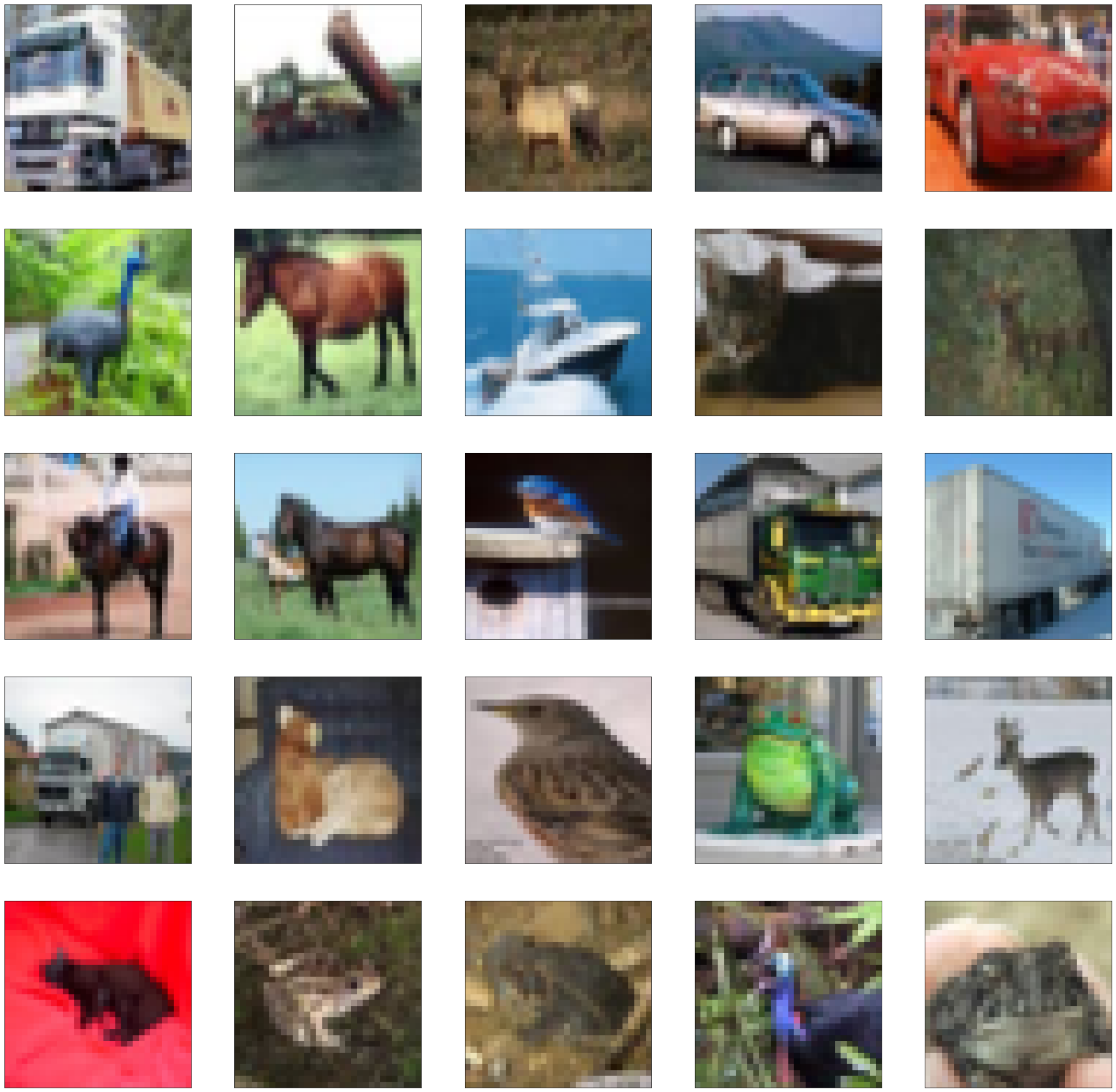
```
Epoch 1/10
50000/50000 [==============================] - 9s 184us/step - loss: 0.5784
Epoch 2/10
50000/50000 [==============================] - 7s 141us/step - loss: 0.5631
Epoch 3/10
50000/50000 [==============================] - 7s 138us/step - loss: 0.5622
Epoch 4/10
50000/50000 [==============================] - 7s 137us/step - loss: 0.5618
Epoch 5/10
```

```
50000/50000 [==============================] - 7s 139us/step - loss: 0.5615
Epoch 6/10
50000/50000 [==============================] - 7s 140us/step - loss: 0.5614
Epoch 7/10
50000/50000 [==============================] - 7s 138us/step - loss: 0.5613
Epoch 8/10
50000/50000 [==============================] - 7s 138us/step - loss: 0.5611
Epoch 9/10
50000/50000 [==============================] - 7s 139us/step - loss: 0.5611
Epoch 10/10
50000/50000 [==============================] - 7s 139us/step - loss: 0.5610
```

[ ]:
```
plot_df = pd.DataFrame.from_dict({'train_loss':history.history['loss']})
plot_df.plot(logy=True, figsize=(15,5), fontsize=12)
plt.xlabel('epoch', fontsize=12)
plt.ylabel('loss', fontsize=12)
plt.show()
```



[ ]:
```
# Visualization of 5 x 5 denoised images
fig = plt.figure(figsize=(32,32))
ind = 1
for i in range(1, 6, 1):
    for j in range(1, 6, 1):
        fig.add_subplot(5,5,ind)
        show(x_images[ind])
        plt.xticks([])
        plt.yticks([])
        ind+=1
```



5.4 Comparison between original, noisy and denoised images

- 1st column: original image
- 2nd column: noisy image
- 3rd column: denoised image

Images in training set

[ ]:
```
# Visualization of 9 x 3 images
fig = plt.figure(figsize=(32,32))
ind = 1
for j in range(1, 10, 1):
    #----------------------------
    # original images
```

```
    fig.add_subplot(9,3,ind)
    show(x_images[j])
    #-----------------------------
    # noisy images
    fig.add_subplot(9,3,ind+1)
    show(x_train_noise[j])
    #-----------------------------
    # denoised images
    fig.add_subplot(9,3,ind+2)
    show(np.squeeze(autoencoder.predict(np.expand_dims(x_images[j], 0))))
    #-----------------------------
    plt.xticks([])
    plt.yticks([])
    ind+=3
```

```
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```

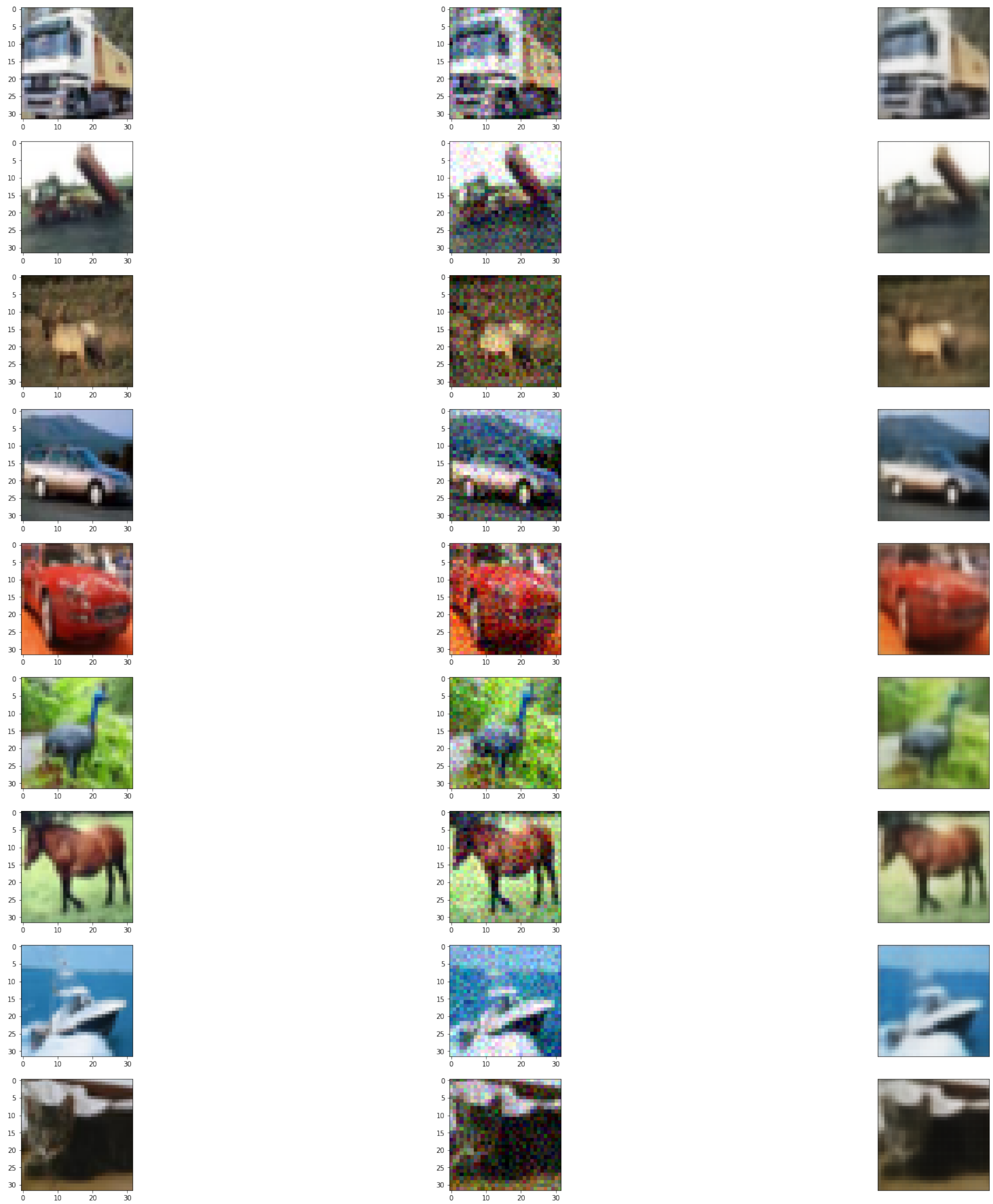

Images in test set

```
[ ]: # Visualization of 9 x 3 images
     fig = plt.figure(figsize=(32,32))
     ind = 1
     for j in range(1, 10, 1):
         #----------------------------
         # original images
```

```
    fig.add_subplot(9,3,ind)
    show(x_test[j])
    #-----------------------------
    # noisy images
    fig.add_subplot(9,3,ind+1)
    show(x_test_noise[j])
    #-----------------------------
    # reconstructed images
    fig.add_subplot(9,3,ind+2)
    show(np.squeeze(autoencoder.predict(np.expand_dims(x_test_noise[j], 0))))
    #-----------------------------
    plt.xticks([])
    plt.yticks([])
    ind+=3
```

```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
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```

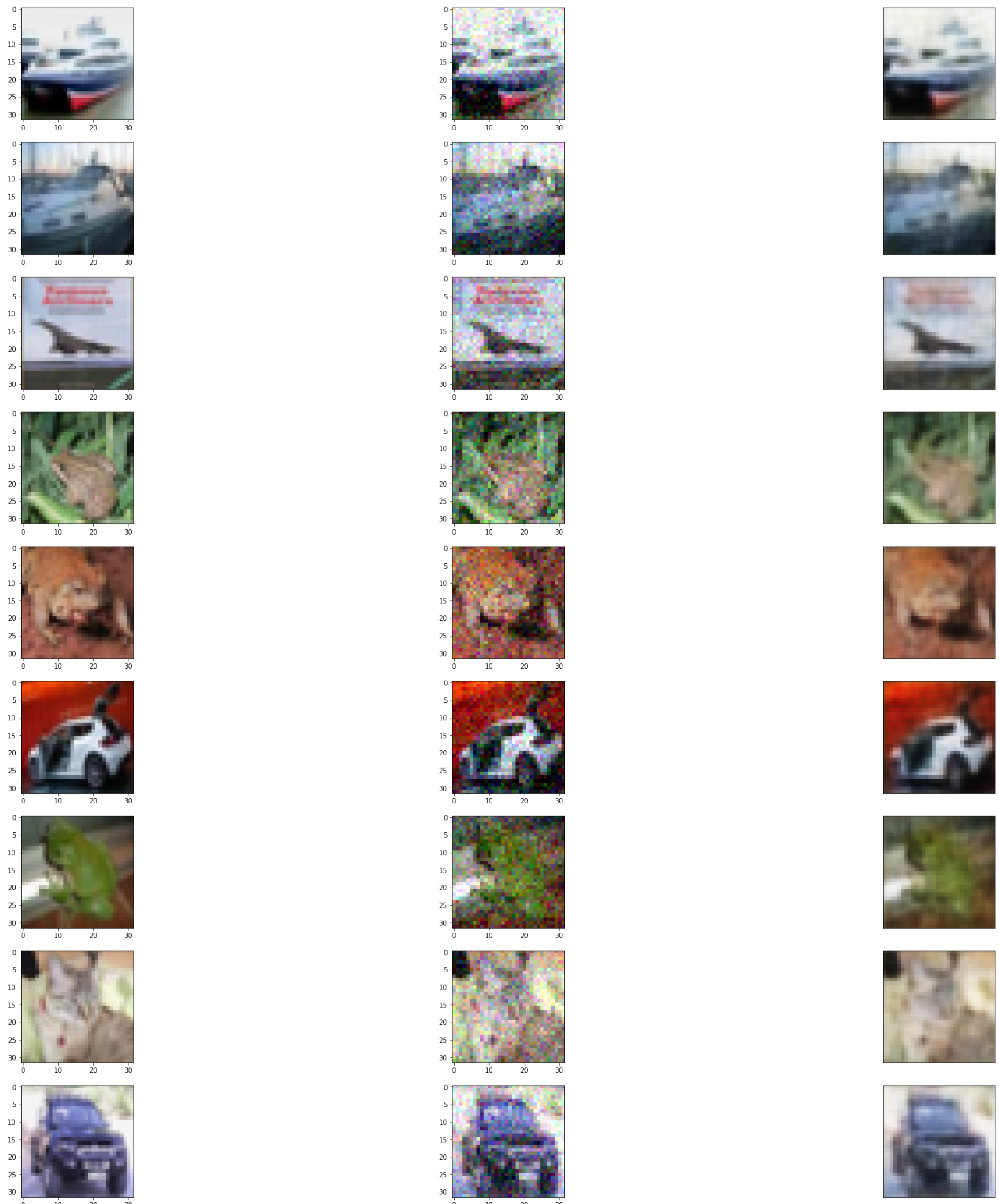

Comments:
As we can see, the DAE (Denoising Autoencoder) is able the remove noise from images. The denoised image is somewhat distorced from the original one (as expected), but it still has quality far better than the noisy images.

End of Notebook